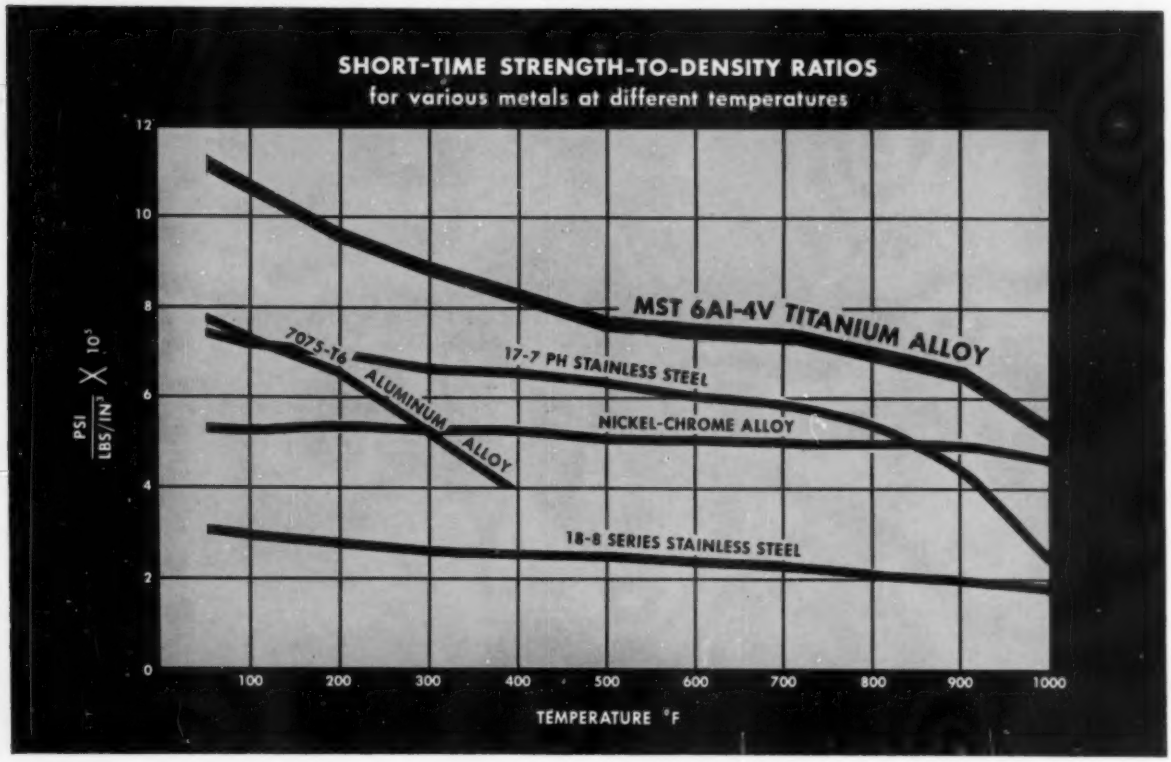
Metal Progress

October 1957

Progress with **TITANIUM**



TITANIUM ON TOP

in medium-high temperature range

Today's most popular titanium alloy, MST 6Al-4V, excels all other metals in strength to density ratio through 900°F. At room temperature, considering only strength, a part made of this alloy need have only 60% of the weight of the equivalent part in stainless steel.

Performance for extended times at elevated temperatures is likewise good. In typical creep tests, with 1% permanent deformation allowed, MST 6Al-4V alloy shows 100,000 psi allowable stress at 750°F for 1 hour; 77,000 psi at 100 hours; 65,000 psi at 1000 hours.

Meanwhile new alloys extending the elevated temperature usefulness of titanium—to as high as 1000°F—are now emerging from the laboratory into production.

Write Dept. F-10 for copy of "Titanium Alloy **Properties**"

SELECTION GUIDE TO MST ALLOYS

Typical Mechanical Properties of Annealed Titanium and its Alloys

	Form	Ultimate Tensile Strength, psi	Yield Strength, psi	Elongation %*
COMMERCIALLY PURE TITANIUM				
MST Grade III	Sheet, Bar	70,000	50,000	25
(3 different strength levels)	Sheet, Bar	85,000	65,000	23
	Sheet, Bar	100,000	80,000	20
TITANIUM ALLOYS				
MST 6Al-4V				
Annealed	Bar	140,000	130,000	15
Age hardened (1)	Bar	165,000	155,000	12
Age hardened (2)	Bar	180,000	165,000	10
Annealed	Sheet	140,000	125,000	12
MST 3Al-5Cr	Bar	155,000	145,000	13
MST 4Al-4Mn	Bar	150,000	140,000	14
MST 8 Mn	Sheet	137,000	125,000	16

(1) 1650°F—1 hour—WQ; 1100°F—2 hours—AC
(2) 1700°F—1 hour—WQ; 1000°F—8 hours—AC

WQ—Water Quench
AC—Air Cool

* Values for 1" on bar and 2" on sheet

MALLORY Ti SHARON

MALLORY-SHARON TITANIUM CORPORATION · NILES, OHIO

Producers of titanium and titanium alloy sheet, strip, plate, rod, bar, billets

Metal Progress

Volume 70, No. 4

October, 1957

Cover, by FLOYD E. CRAIG, typifies the badge to be worn by conferees to the Second World Metallurgical Congress.

National Metal Congress and Exposition; 2nd World Metallurgical Congress

Technical Programs of Cooperating Societies 66

Exhibitors and Booth Numbers, National Metal Exposition 91

Engineering Articles

Economics of the New Iron Ore Reduction Processes, by E. C. Wright 99

A ton of steel from all direct iron processes requires at least 4,000,000 Btu. more energy than from the conventional blast furnace and openhearth, and consequently a direct iron plant must be located where electricity or gas is very cheap and coke is very dear. There is little difference in capital costs per ton per year. (D8, B15; Fe, RM-n)*

Atomic Fuels, by Frank H. Spedding 105

Several fissionable isotopes will be available to fuel the future power reactors, and could be used as solid metal or alloy, as a molten mixture or in liquid solution. Various coolants and moderators are also possible. To determine which combination of all these can best produce economical electricity is the aim of the Atomic Energy Commission's extensive and costly development program. (T11g, W11p; U, Th, 14-13)

The Future of High-Temperature Metallurgy, by L. P. Jahnke 113

Future advances must be conceivable, feasible and desirable. On this basis the author considers the effect of purity (both chemical and structural), especially of alloys based on columbium, molybdenum or tungsten, and predicts that by A. D. 2000 we will have alloys of useful strength up to 5500° F. (Q27a, 2-12; SGA-h)

What's in the Literature? by Frank T. Sisco 122

Searching of metallurgical literature is now so costly in time of high-grade men that it is frequently cheaper to get a direct answer by laboratory research than to find out whether someone else has recorded his findings. It is hoped that machine searching of metallurgical literature will correct this situation, at least in the field of metals. (A14e)

Testing of Welded Aluminum Hopper Cars, by J. F. Whiting 125

About 150 aluminum freight cars of three designs have been made by Canadian car builders. To devise improvements strain gages were placed at strategic positions on full-sized hopper cars. Stresses were measured during static, shakeout and impact tests simulating actual service conditions. (T23P, 17-7, S21; Al; Al, 17-1)

Induction Heating for Merchant Mill, by R. S. Segsworth 129

Billet-sized ingots are pushed end to end through a long induction coil, the first half of which receives 60-cycle current and the second half 540-cycle current. A 6⅝-in. square reaches rolling temperature in 8.4 min. Indicated scale loss of 3% in oil-fired heaters has been reduced to less than 1%. (W20h; 1-19; CN)

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METAL PROGRESS is published monthly by the AMERICAN SOCIETY FOR METALS. Publication office, Mt. Morris, Ill. Editorial, executive and advertising offices, 7301 Euclid Ave., Cleveland 3, Ohio. Subscription $7.50 a year in U.S. and Canada; foreign $10.50. Single copies $1.50; special issues $3.00 . . . The A.S.M. is not responsible for statements or opinions in this publication.

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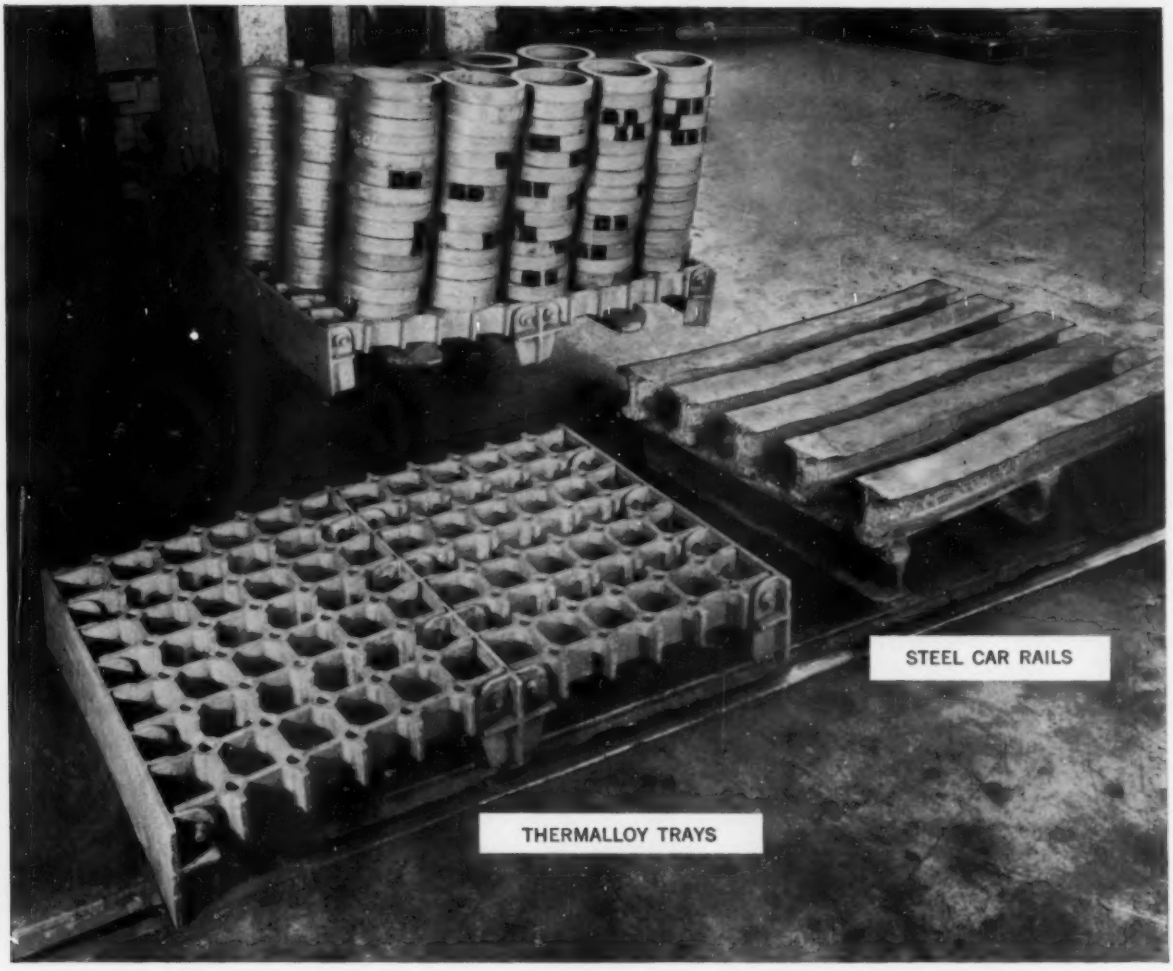
READERSHIP RESEARCH

**The coding symbols refer to the ASM-SLA Metallurgical Literature Classification, Revised Edition, 1957*



Thermalloy* Heat-Resistant Trays Cut Costs for SKF Industries

At SKF Industries in Philadelphia, steel forgings are annealed in a car-type furnace at temperatures between 1450 and 1650 degrees F. Steel car rails were used to support the forgings in the furnace. But these warped and scaled after short service and became useless.

At the same time, SKF tried the specially designed trays of Thermalloy "30" shown above. These trays have given *six times the service life* obtained from the rails—and are still in use, with many more months of service left. In a cost comparison with the steel rails, SKF found that the Thermalloy trays were less expensive, considering *only* their service life to date.

Thermalloy heat-resistant alloys and Electro-Alloys' design know-how are providing longer service life in scores of heat-treat applications and are saving money for users.

Whatever your heat-treat problem, it pays to contact Electro-Alloys. For further technical information on Thermalloy trays and fixtures, call your nearby Electro-Alloys representative or write for Bulletin T-227. Electro-Alloys Division, 80310 Taylor St., Elyria, Ohio.

*Reg. U. S. Pat. Off.

AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION Elyria, Ohio

Vacuum Induction Melting – Process Considerations, by W. E. Jones 133

Successful vacuum melting requires very high vacuums, leak-tight equipment, pure melting stock and crucible materials. Reactive metals added at the end of the heat then alloy with the melt rather than form undesirable inclusions. Notable improvements result in properties of heat resistant alloys. (C5, 1-23; SGA-h, Ni, Co, Fe, 5-9)

Progress in Magnesium, by H. G. Warrington 139

Unlimited ore supplies, well-developed reduction and fabrication processes, light weight and other inherent advantages, together with continually improved alloys, foreshadow enlarged consumption for all sorts of machinery in motion, for nuclear reactors, and for consumer goods. (A general, 17-7; Mg)

Advances in Nondestructive Test Methods, Staff Report 143

Five individual tests are made on each tube accepted for a nuclear reactor – visual, fluorescent penetrant, X-ray, eddy current, ultrasonic. Latest devices in these fields are outlined, together with "Photostress", where surface stresses are estimated from the reflection of polarized light from a plastic sheet cemented to the part. (S13, 1-3)

Atomic Age

Our Grandchildren – More Power to Them, by Thomas L. Shipman 112

The atom – with its untapped power resources – should be looked upon as the hope, not the downfall, of future generations.

Data Sheet

Hardenability Bands for Steels 1330-H to 3310-H 112-B

Revised curves issued by American Iron and Steel Institute, March 1957.

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A Survey of American Foundry Practices, Reviewed by George F. Watson 119

"Principles of Metal Casting" by Richard W. Heine and Philip C. Rosenthal.

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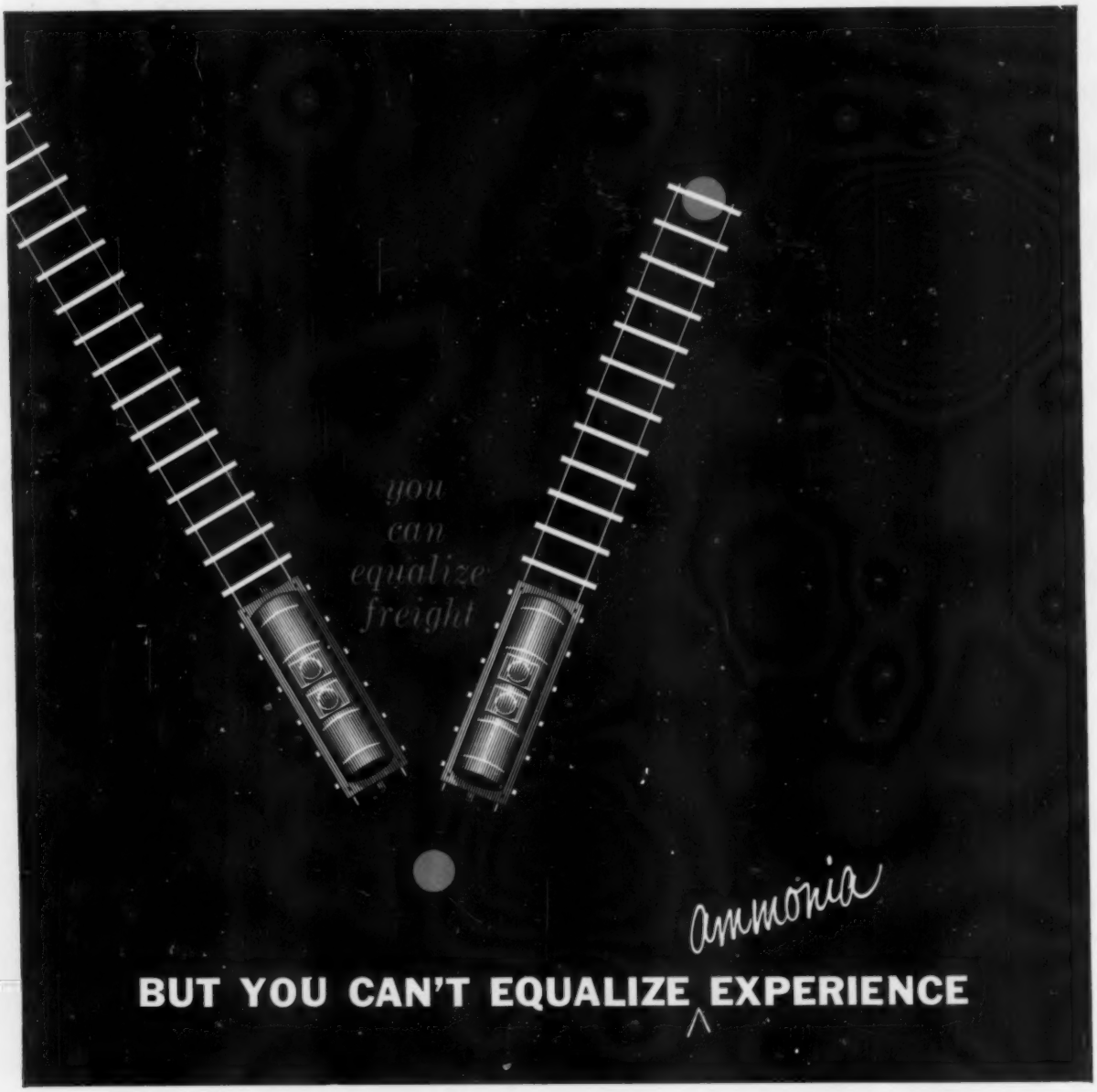

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As I was saying...

OCTOBER is a busy month for all of us at headquarters. It's convention time (although this year it comes the first week in November) and that brings along myriads of things that have to be planned and ordered. You may not believe it but even the coffee-break during the technical sessions takes advance preparation – and rightly so, for who would like to serve coffee to 1000 guests if he had notice only the evening before? And with 25 educational institutions having alumni luncheons on Wednesday – with the alumni too busy with other activities to purchase tickets in advance (only 150 luncheon tickets sold by Wednesday noon and 800 fed) – we have to use the statistical quality (quantity) control principle and determine by trig and calculus, and by applying the theory of probable room-elasticity, the number that will show up. Ten years' practice in working out this problem has made Al Hess (assistant treasurer) an expert and he loves it.

The attendance of 500 overseas conferees will be the culmination of approximately two years of planning. The response has been beyond all expectations and the distinguished list of conferees insures the success of the Second World Metallurgical Congress.

With all the special activities planned by the cooperating societies, as well as the SNT's hosting of the Second World Congress for Nondestructive Testing and the 20 panels of the American and Overseas Conferees, the program is indeed a busy one – and so rich in possibilities that it will linger long in the memories and hearts of all ASMers.

And don't forget the Expo with 487 exhibitors occupying more space than any other show in A.S.M. history. Lots of new processes, equipment and products – a feast for the inquiring mind. There'll be bus service at 15-minute intervals from all downtown hotels to and from the International Amphitheatre.

Hey fellers! There's a four-page ad in this issue of *Metal Progress*, p. 360-A, that I hope you'll have time to read. It's the first public spread of information about the Metals Engineering Institute courses. As you may know, M.E.I. is not intended to produce metallurgists but technicians, people who are reporting to you, who are in the metals industry and wish to up-grade their knowledge and capacity for advancement. That's the way Pete Ford wrote the ad, for your information so you could call it to the attention of those depending on you for counsel and advice. Yet some of you personally may wish to know the fundamentals about some of the newer materials and processes, and will want to investigate the M.E.I. for yourselves.

Here's news – the Trustees have selected an architect and accepted his design for the headquarters building. The completed sketches and drawings will be available soon; just a few details on the engineering phases are yet to be determined. They may be complete by convention-time. If so I'll spill the beans (plans) at the annual meeting. I feel this building with its dramatic appearance and unusual distinctiveness will surprise and thrill you as it has us – and make you proud of the A.S.M. and happier still because another of the principal features of the A.S.M. of Tomorrow is now becoming a reality.

See you in Chicago!

W. H. EISENMAN, *Secretary*
AMERICAN SOCIETY FOR METALS

Bill

test hardness of

CASTINGS
FORGINGS
BARS

the *best* way with Steel City Brinell Testers

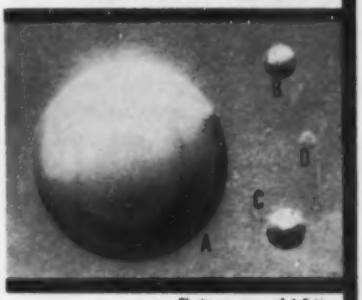

Photo courtesy of A.S.M.

Photograph illustrates the comparative size of impressions made by four different types of hardness tests:

(A) Brinell, (B) Rockwell "B", (C) Rockwell "C", and (D) Scleroscope. Because it covers a larger area, the Brinell impression (A) averages out small inequalities in hardness, surface finish, and complex internal conditions of the metal.

Steel City Brinell Hardness testers are designed to efficiently provide a *true* picture of the hardness of castings, forgings, bars and other comparatively rough and soft forms of metal. Models are available to facilitate the handling of the work with minimum of effort. *True, round Brinell impressions assure dependable testing results.* If a Brinell Hardness test is indicated for your material or product — contact Steel City for the *right* testing machine.

If one of the following types of test is your need—let us help you choose the Steel City machine that meets your individual requirement.

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See Steel City's exhibit Metal Show—Booth 1729

Dallas Metal Show has been added – to your Sales Territory . . .

The great Southwest – the industrial Southwest—rich, growing, bustling – is waiting for you. Here's a new sales territory that means profits for modern-day pioneers.

There'll be thousands of *new* prospective customers who'll crowd the Southwestern Metal Show – to see your company's display – to hear your company's story – to buy your company's product.

Over two million people live and work within a day's drive of Dallas. They are your prospects, interested in all that's new and improved. This is a chance you can't afford to miss.

Mark those five days next May as the "Days that Pay". You'll find them just that, because thousands will be at the Dallas Metal Show, searching for production advantages that will help improve operations, services, products – and at lower costs.

These prospects will be ready to buy. They'll be "preconditioned" – for the great Southwest is on the march, sparking sales to improve its own business economy.

ASM Metal Shows are famous as sales stimulants. They are "musts" for any firm with an eye on an expanded tomorrow. Here in the Southwestern Metal Show is a rich metal market full of opportunity for the prospecting manufacturer. Here's a show that will out-draw, out-sell and surpass anything you've experienced before in the "great open spaces."

STATE FAIR PARK

DALLAS, TEXAS

MAY 12-16, 1958

Because the Show is staged in Dallas' spacious State Fair Park, only two miles from the city's center and downtown hotels, you'll be able to put your best foot forward before a top level audience looking for just what you've got to offer. There never was a finer exhibition hall – all on one level – airy, bright. It puts visitors in the right frame of mind to buy. It will be bristling with ideas and thronged with buyers.

Get your share of this new market. The Southwestern Metal Show is the place to sell! Act today – select your space. If you don't have floor plans, write us NOW. You'll reap a harvest from this new and finer Metal Show. To assure success in '58 – Don't Hesitate!

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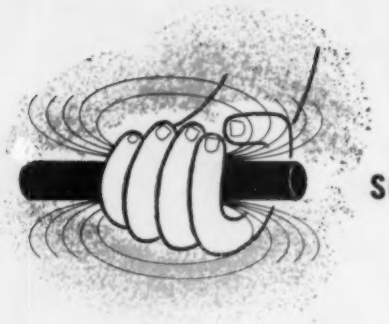


some straight talk on AJAX technical service

When you come right down to it, "technical service" is mainly a question of *experience* . . . the service is only as good as the experience behind it and the willingness of the manufacturer to share this experience.

Ajax has the savvy, will share

It almost embarrasses us to talk about experience in the field of induction heating & melting. *Ajax firsts* read like a history of induction technology—because they are!

The *first* high frequency induction furnace was fathered by our company some 41 years ago. As early as 1920, Ajax was supplying *vacuum* furnaces to National Bureau of Standards and others. Practically every new alloy developed since that time had its origin in an Ajax-Northrup induction furnace. These Ajax firsts go on and on . . . from melting, forging, surface hardening, vacuum melting . . . to making, sintering, and hot pressing carbides, graphitizing, uranium melting, and countless other low, dual, and high frequency applications.

These are the proofs of what Ajax Technical Service can do . . . pointing to what it can do for you and your company. Sharing this experience helps you, helps us.

Service a la carte

Now, no user or potential user of induction equipment wants or needs *all* our experience, even if it were possible to give. The practical sharing of our experience amounts to matching what we know about induction technology to *what you want to know about it.* This can vary quite a bit from job to job.

If, for example, you're considering induction heating & melting for the first time, you'll want to know a great deal about its basic advantages and how it compares in cost and performance with your present equipment.

Or suppose, on the other hand, you already have induction equipment and would like to improve its efficiency and decrease maintenance cost. Perhaps in this case Ajax can supply some pertinent test data on optimum temperatures and pour schedules, or some valuable tips on refractory ramming techniques that will save many hours in furnace maintenance.

Regardless of the type of engineering service you require in the field of induction heating & melting—whether it be general or specific, basic or advanced —Ajax is ready with savvy, will share! Ajax service engineers will be glad to analyze your heating and melting problems and make detailed recommendations. If induction is the answer to your problems, they will help you select the type of equipment best suited to your specific application . . . help you operate this equipment to obtain highest performance, maximum production . . . design new equipment if necessary.

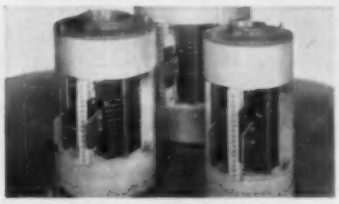
you can look to AJAX for progress in induction heating & melting

Ajax technical service helps put induction heating & melting to work

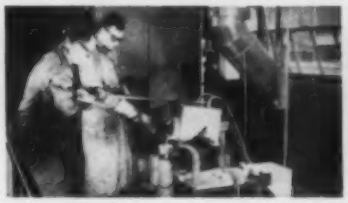
Listed below are a number of examples illustrating the length and breadth of Ajax experience in specific areas of induction heating & melting. Our direct experience in these and other areas may bring real dollars and cents savings to your operation. It's worth investigating! To start the flow of valuable induction heating & melting ideas in your direction . . . to get the most out of your induction equipment—just call or write Engineering Department, Ajax Electrothermic Corporation, Trenton 5, New Jersey.

in research and development

melting uranium for Atomic Energy Commission
During the earliest years of our nation's atomic energy program, substantially all uranium used was melted by high frequency induction heat in specially designed Ajax-Northrup furnaces.

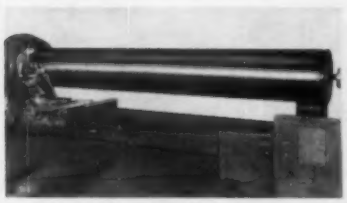


research in high temperatures
Ajax-Northrup high temperature furnaces are especially designed to provide fast, efficient heat at temperatures from 1200°C to 2000°C and above.



developing new alloys and alloying techniques
Many of the country's largest laboratories use Ajax-Northrup induction furnaces in studies of new alloys and for pilot-plant operation prior to large scale production.

in production

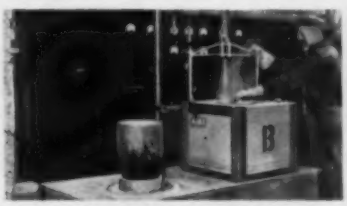


casting world's largest stainless steel centrifugal castings
At Sandusky Foundry and Machine Co., Ajax furnaces of up to 5 tons capacity melt metal for centrifugal castings weighing up to 20 tons.

improving operation of investment casting foundry
Precision Metalsmiths, Inc., finds Ajax-Northrup furnaces ideal for melting some 92 different ferrous and nonferrous alloys. They give fast heat, produce alloys of the highest purity.

melting and pouring six tons of metal every 2½ hours
This Ajax-Northrup induction furnace turns out a six-ton charge of nickel alloy —precisely alloyed and virtually free of impurities—every 2½ hours. Speed of melting and electromagnetic stirring insure perfect alloys every time.

mechanizing giant forge shop
Imaginative forge design, plus the inherent flexibility of Ajax induction heating, make it possible to operate giant Massey-Harris-Ferguson forge shop with just three induction units . . . each equipped with seven heating fixtures.

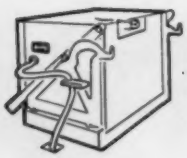


saving $33.00 per ton in nonferrous foundry
Ajax-Northrup furnaces produce big savings for City Pattern Foundry & Machine Co., Detroit. With nonferrous alloys, savings of over $33.00 a ton are reported in reduced metal losses, labor, and refractory.

vacuum melting in ever increasing capacities
The photo illustrates the first 1000-lb. vacuum furnace Inductivac© which is now in production at the research and development center of Universal-Cyclops Steel Corp., General Offices, Bridgeville, Pa. This furnace incorporates Ajax-Northrup induction furnace and controls.

see them at the show new AJAX designs and improvements

Though far from "revolutionary," these new designs and improvements will bring considerable handling ease and increased productivity to present day induction equipment. Exactly how these Ajax innovations will help you in your specific application can be best discussed with our engineers at the show.

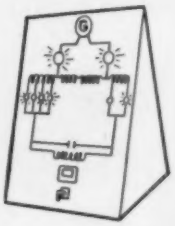


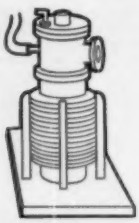
new type of co-ax leads

An Ajax-Northrup 300# furnace will be equipped with new type of co-ax side mounted leads that are being studied by our engineering staff.

operating switch exhibits

Here are two exhibits you can "work" yourself. One powercontrol shows how the Ajax tap switch operates. The other demonstrates the exclusive Ajax rotary capacitor switch, designed for exceptionally fine power factor control.





new vacuum furnace top

One of our stationary cylindrical vacuum furnaces will be fitted with a newly designed vacuum top.

induction furnace ramming tools

Developed and proved at Ajax's own manufacturing plant, these ramming tools will improve the life of furnace linings. You'll want to look them over carefully . . . operate them . . . learn how to improve your ramming techniques.

space-saving vertical motor-generator

Visitors to the Ajax booth will also see a totally enclosed, water-cooled, vertical motor-generator rated at 100 KW, 3000 cycles.

improved safety features

Operating display demonstrates improved type of molten-metal leak and ground detector.

SEE YOU AT BOOTH 1406 . . . BE SURE TO STOP IN . . . YOU'LL LIKE THE COMPANY

Induction heating & melting

AJAX

NORTHRUP

Special Literature Offer

At the show Ajax will be offering an impressive collection of valuable and useful information in practically every phase of induction technology. Be sure to look this collection over carefully . . . choose the bulletins, booklets, and articles that will help *you* get the most out of induction heating & melting.

AJAX ELECTROTHERMIC CORPORATION, Trenton 5, N. J.

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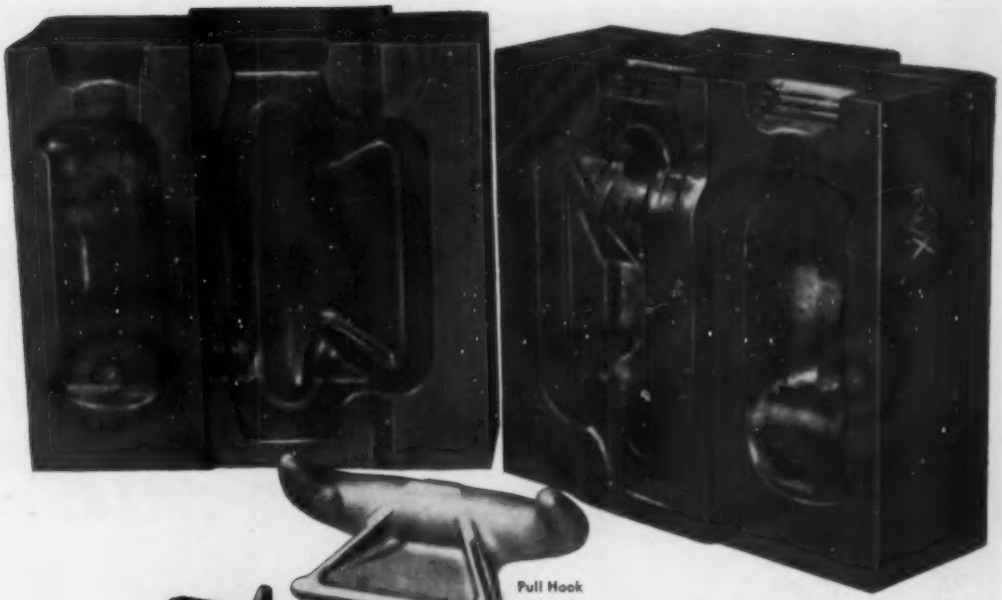

Pull Hook

Pivot Shaft and Bracket

Equalizer Spring Saddle

USE FINKL DIE BLOCKS FOR QUALITY FORGINGS...

farm equipment manufacturers do!

Track Link

Draw Bar Bracket

International Harvester Company's Tractor Works, for one, uses Finkl die blocks to produce numerous tractor parts such as the pivot shaft bracket, pull hook, track link, equalizer spring saddle, and draw bar bracket shown on this page.

Because of the high volume production of these Crawler Tractor parts, Finkl FX die blocks are used at Harvester's Tractor Works to produce more forgings per sinking, and more sinkings per die. The special machining quality reduces die sinking time, without impairing the heat or wear resistance of the dies in production.

Finkl die blocks are available in several grades, all sizes, and tempers to handle virtually any forging requirement. Call your local Finkl representative next time you are considering die blocks or forgings. He will be glad to help you and there is no obligation.

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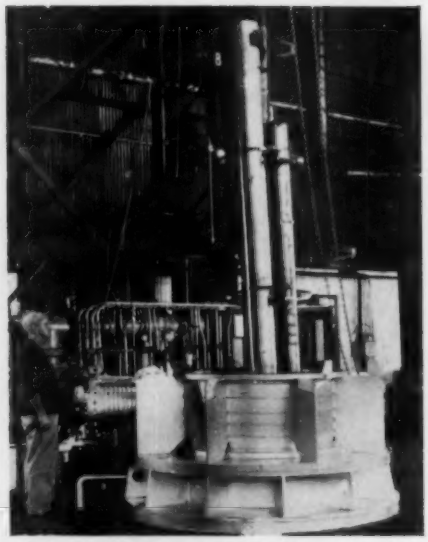
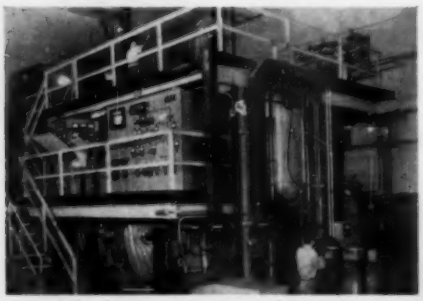
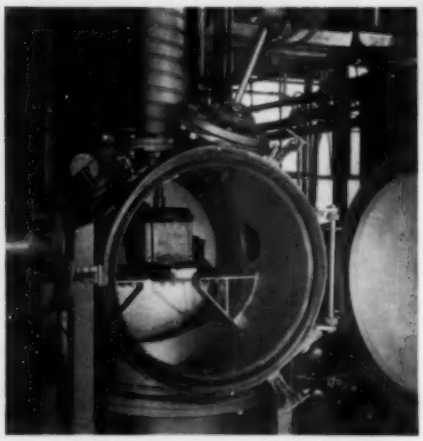


Vacuum Resistance Pit-type Furnace, used by Rem-Cru Titanium, Inc., to heat treat titanium mill products up to 12 ft. long by 4 ft. wide. Standard resistance furnaces available in bell, pit, and horizontal muffles with hot zones from 2″ to 54″ I.D.



World's largest vacuum induction furnace with 3000 pounds capacity, installed at Crucible Steel Corporation of America. Capacities of standard induction furnaces range from 12 to 5000 lbs. of molten steel.



Vacuum Arc Furnace has interchangeable consumable and nonconsumable electrodes for melting into either cold mold or skull for titanium shape castings. Standard arc furnaces available from 10 to 10,000 lbs.

For about two bits you can get a pound of air-melted 52100 alloy steel. However, impurities introduced by air-melting are a prime cause of failure in high stress or high temperature parts. Vacuum-melted 52100 costs nearly $2.00 more, but what a difference in performance! For instance, it adds 600% to the life of a jet engine thrust bearing. And because it is "cleaner" and easier to work, it often saves shop time and reduces rejects.

The benefits of vacuum melting are especially spectacular in the case of "superalloys" used for high temperature applications such as jet engine blades and rotors. One blade producer found that replacing air-melted with vacuum-melted superalloy increased stress rupture life 40%, ductility 100%, and tensile strength 12%. Best of all, it halved the cost per satisfactory blade!

Vacuum pays for itself outside the aircraft industry, too. Included on the growing list of high performance products benefit-

ting from its use are bearing races, jewelers rolls, bolts, precision castings, valve springs, chemical process equipment, dies, electronic tubes, and watches. Besides improving the strength, composition control, cleanliness, life, corrosion resistance, conductivity, ductility, and workability of existing materials, vacuum melting allows you to develop new alloys which are impossible to produce in conventional furnaces.

If you'd like to know whether vacuum metallurgy can improve your product and cut your costs, let us know. We'll be glad to share the knowledge we've gained from building and operating more high vacuum furnaces than any other organization in the world. If you decide to conduct your own vacuum metallurgical operation, you'll find that NRC is your one convenient source for a complete line of vacuum arc, induction, and resistance furnaces with capacities from a few pounds to several tons. Write today.

See us at Booth No. 1426 at the Metals Show Nov. 4-8, Chicago

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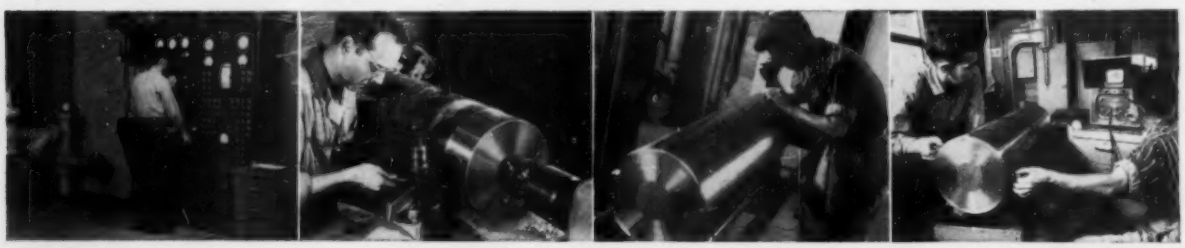
Ask to be placed on the mailing list of "More ZR Facts," the zirconium industry's first continuing source of technical information.



● Ingot melt control panel scientifically regulates atmosphere and melting conditions through first and second melts.

● Operator mechanically conditions zirconium ingot to remove surface irregularities from cast ingot wall.

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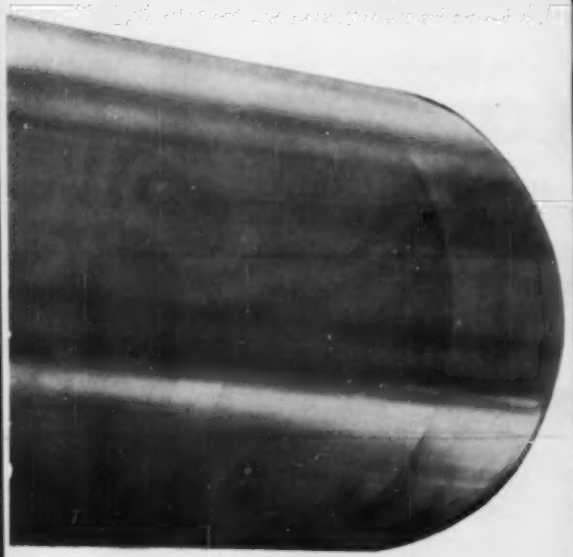
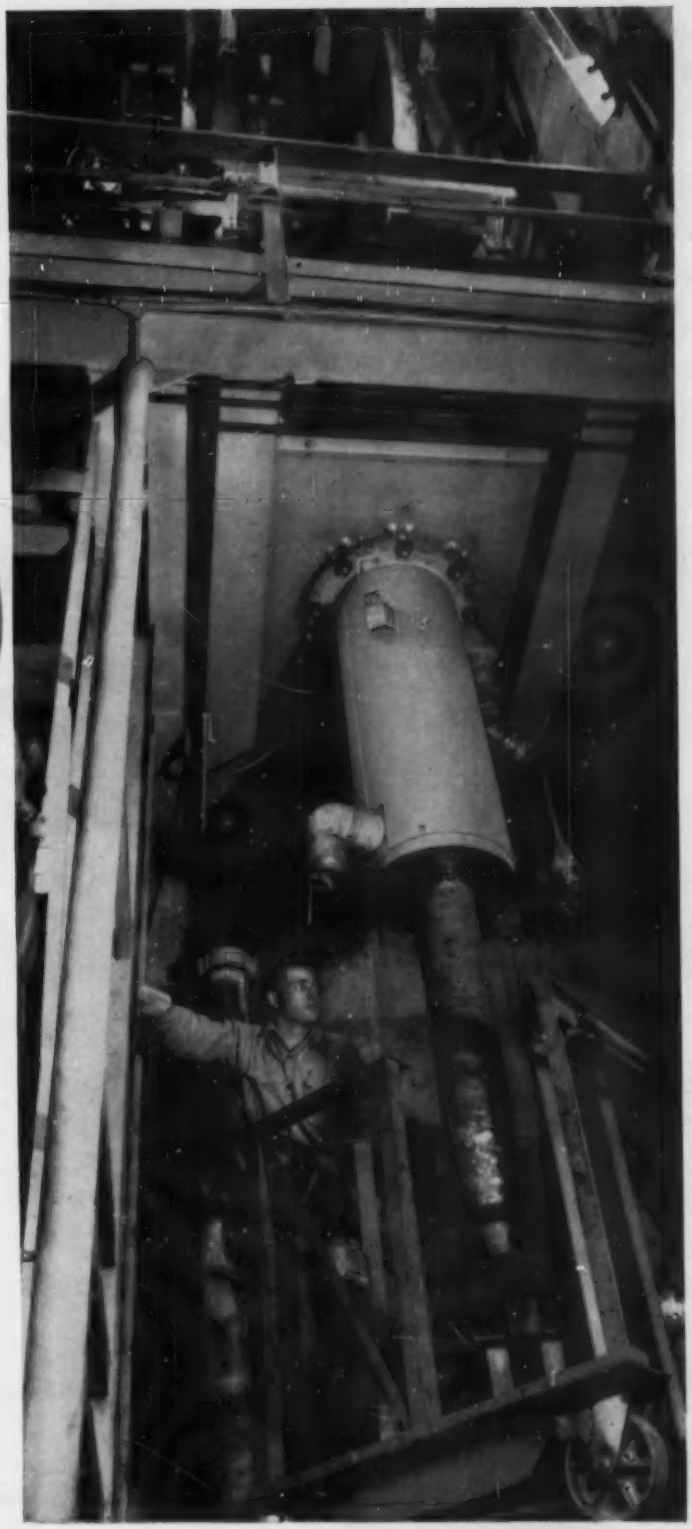
SECOND MELT certified ingot ready for fabrication. Ingots are produced from 500 to 2500 lbs. each in 12" to 16" diameters. From zircon sand to zirconium ingot by *one* manufacturer—quality controlled all-the-way with Proven Methods, Proven Quality and Proven Performance.





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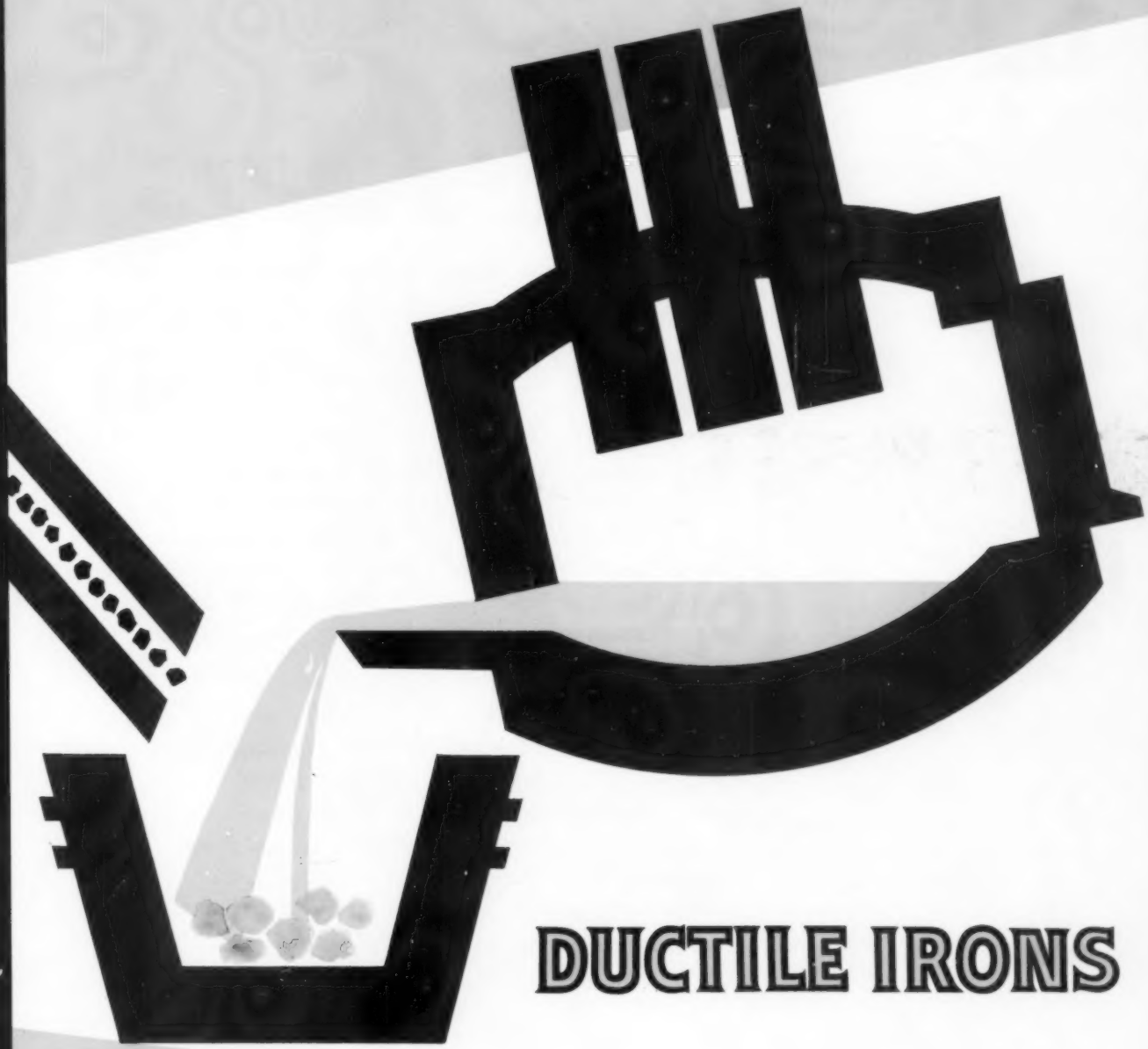

DUCTILE IRONS

a new family of metals for industry

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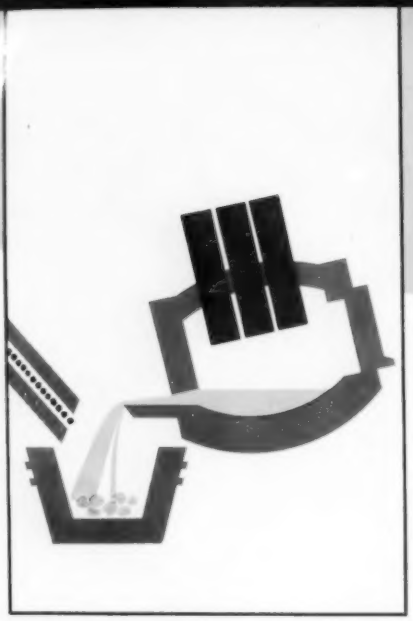

ANOTHER ELECTRIC

Today, many foundries are close metallurgical control

DUCTILE IRONS

This relatively new family of cast metals has proved the most outstanding foundry development since malleable iron.

Today, industry has available to it a relatively new material known as ductile irons. Unlike ordinary cast iron, ductile irons can be bent, twisted, drawn or otherwise deformed without fracturing. These ductile irons, to a large degree, bridge the gap which long existed between cast iron and steel.

Ductile irons have the processing advantages of cast iron — good fluidity and castability, ready machinability and low melting point — combined with many of the engineering advantages of steel — good strength, toughness, heat resistance and substantial ductility. Ductile iron has several times the strength of ordinary gray iron, exceptional resistance to impact shock and excellent resistance to oxidation and growth at elevated temperatures.

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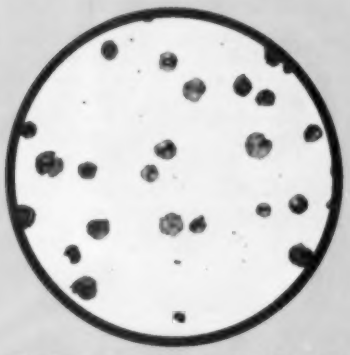
FURNACE PRODUCT...

using the electric arc furnace to achieve the and critical analyses needed for ductile iron.

UNIQUE GRAPHITIC STRUCTURE

Gray iron — random graphite flakes, unetched, magnification 100 X.



Ductile iron — random graphite spheroids, unetched, magnification 100 X.

Ductile iron is cast iron in which graphite is present as spheres or spheroids of characteristic structure, in contrast to the flake graphite in gray iron or compacted aggregates which distinguish malleable iron. Ductile iron is also known as nodular iron, nodular graphite iron, spherulitic iron, spheroidal graphite iron and SG iron.

The total carbon content of ductile iron is the same as that of gray iron. Spherulitic graphite particles are formed during solidification by the addition of a very small percentage of magnesium in the molten metal prior to casting. The startling change in the microstructure achieved by causing the graphite to take a spheroidal shape removes the former weakening and embrittling effects. The graphite now is in a shape which presents the minimum number of surface discontinuities in the surrounding metal, and a far stronger, tougher and ductile material is attained.

DUCTILE IRON SPECIFICATIONS

There are four specifications covering grades of ductile irons as set up by the ASTM. They are designated as 60-45-10, 80-60-03, 100-70-03 and 120-90-02. The numbers refer, respectively, to minimum tensile strength in 1,000 psi, minimum yield strength in 1,000 psi, and minimum elongation on percent. These specifications are summarized in Table 1.

Type	Typical Range of Mechanical Properties					Specifications
	Tensile Strength psi	Yield Strength psi	Elongation %	Hardness Brinell	Charpy Impact Unnotched (Ft.-Lbs.)	
60-45-10	60/80,000	45/60,000	10/25	140/200	60/115	ASTM A339-55 MIL-I-11466 (ORD.) MIL-I-17166 (SHIPS) (1) AMS #5315 (2) ASTM A395-55T (3)
			(1) Requires 40,000 psi yield and 15% elongation, also specific chemical composition and metallurgical structure. (2) Requires 15% min. elongation. (3) Requires 15% min. elongation, also specific chemical composition and other casting specifications.			
80-60-03	80/100,000	60/75,000	3/10	200/270	15/65	ASTM A339-55 MIL-I-11466 (ORD.) AMS #5316
100-70-03	100/120,000	70/90,000	3/10	240/300	35/50	MIL-I-11466 (ORD.) (4) ASTM A-396-55T
			(4) Requires 75,000 psi yield and 4% elongation.			
120-90-02	120/150,000	90/125,000	2/7	270/350	25/40	MIL-I-11466 (ORD.) ASTM A-396-55T
Heat Resistant (5)	60/100,000	45/75,000	0/20	140/300	5/115	
			(5) Typical composition range: T.C. 2.8/3.8%, Si 2.5/6.0%, Mn .20/.60%, P .10% max., Ni 0/1.5%. Although resistance to oxidation increases with silicon content and is excellent at 6% Si, most castings are purchased at 3.0/4.5% Si which provides the best compromise between mechanical properties and oxidation resistance. This grade is not recommended for applications involving severe thermal shock.			
High Alloy	54/74,000	32/38,000	4/40	140/200	Vee Notched 10 to 28	MIL-I-18397 (SHIPS) AMS #5394

PRODUCTION METHODS

Ductile iron may be produced in the electric arc furnace, acid cupola, basic cupola, carbon lined (neutral) cupola or by duplexing from cupola to the electric arc furnace.

ELECTRIC ARC FURNACE

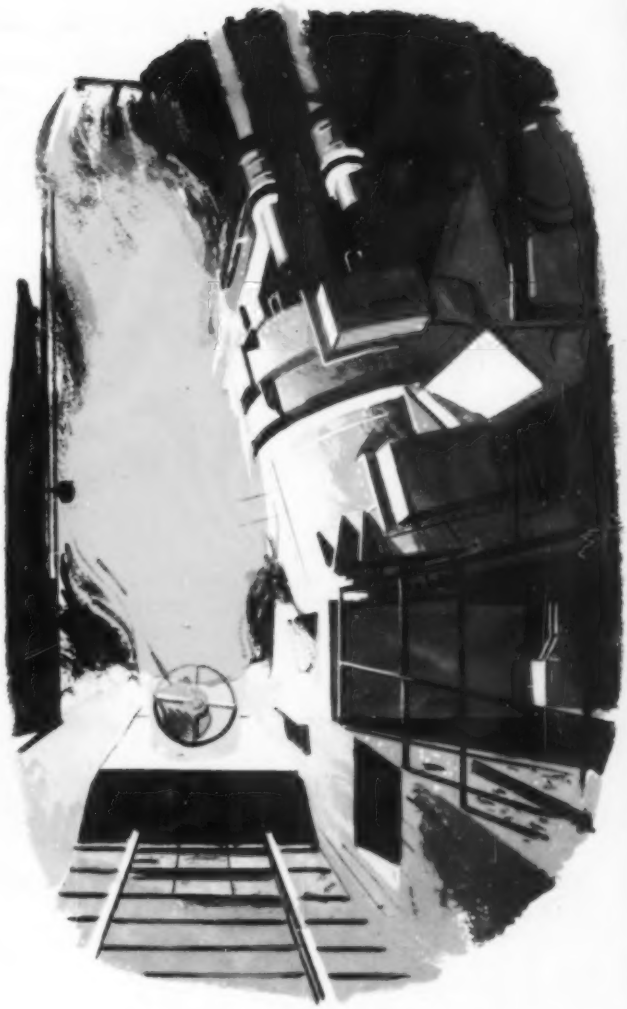
Because of the need for close metallurgical control and high purity analysis of the cast iron used as a base for ductile irons, a substantial number of foundries are now using the electric arc furnace for the same reasons that high quality steels have been made in this type furnace from the beginning.

It has been estimated that approximately one-third of the foundries making ductile irons are using electric furnaces in their operations.

It is now well established that, regardless of analysis, the ease of controlling slag-metal reactions and bath temperatures in the electric furnace make it an ideal tool for the production of close analysis products. The electric furnace not only provides for close chemical reduction and control but there is no further contamination of the bath because the "fuel" – electricity – contains no sulphur or other impurities.

Many foundries making precision ductile iron castings are employing the exceptional control features of the electric furnace in their operations. For example, there is great demand today for the electric furnace in producing Austenitic ductile irons, because, there are more alloys to control and pouring temperatures are more critical.

Some foundries practice duplexing in the electric furnace in conjunction with cupolas. As one foundryman stated, "It's the electric furnace hands-down for this operation." Any attempt to utilize oil or coal-fired holding furnaces would produce too much sulphur in the base metal.



A foundry manager, commenting on the electric furnace for producing ductile iron said, "It's wonderful . . . you can turn it on and off quickly and make up large or small heats as needed."

ACID OR BASIC CUPOLA

Through the years the conventional cupola with an acid lining has been operated purely as a melting furnace with no great chemical refinement expected. Cumulative sulphur absorption and declining raw material quality have made it increasingly difficult to meet the rigid and varied metallurgical specifications with the materials available and the chemical limitations of the acid cupola. The metallurgical requirements of ductile iron present a good example; with a magnesium addition, the final sulphur content of ductile iron will normally be below 0.020 per cent.

In the basic cupola, irons of 0.010 per cent sulphur and 3.90 per cent carbon are not uncommon. This iron requires approximately two-thirds the magnesium alloy addition usually needed for acid cupola iron. From the economic and metallurgical standpoint the basic cupola seems to offer more definite advantages than acid lined cupolas.

Look Ahead— Look Electric

Gives greatest flexibility—
Makes any steel—any time—from stainless to plain carbon. Handles cold scrap, metallics, hot metal. Starts, stops quickly — gives faster melts.

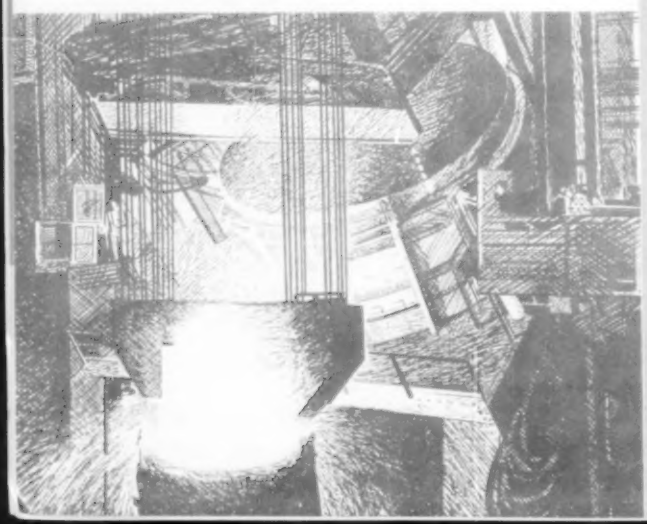
Delivers highest quality product—
Closer temperature control possible.

Lowers capital investment—
40% less than equivalent open-hearth capacity.

Saves space—
Savings of 25% and more vs. open hearths producing same tonnage.

Goes up fast—
Capital investment pays off sooner.

Uses clean fuel—electricity—
No combustion products to contaminate melt.



CARBON LINED CUPOLAS

Cupolas having carbon linings in the well area have proven superior in the production of ductile irons with respect to lining life and maintenance costs, and also assure close chemical and metallurgical control as required. The first installations of carbon linings were made by companies operating basic cupolas which had experienced high refractory costs due to the corrosive action of the basic slag. Full advantage has been taken of the high corrosion-resistant and chemically neutral properties of carbon. There are many cupolas operating in the United States today with "National" Carbon linings.

PRODUCTION TECHNIQUES

Due to the excellent fluidity characteristics of ductile iron in the molten state, thin sections cast as easily as thick sections. If thin section castings are desired, a charge of 100% pig iron will cast exceptionally well. But, the high carbon content of this molten metal (3.8 to 4.0%) will cause carbon flotation when cast in thick sections. Therefore, if thick section castings are on production schedules, operations will proceed much smoother when the charge is calculated to reduce carbon content of the base material to roughly 3.5 to 3.8 per cent. This can be accomplished by adding steel to the charge or better still, by employing the revert (gates and risers) from previous ductile iron castings, adding steel, and utilizing a carbon raiser in pellet form.

From tap-out to casting the process for ductile iron is similar regardless of the charge. The base metal is tapped into a ladle containing a magnesium alloy to provide a sufficient amount of retained magnesium necessary to promote spheroidal graphite. The bath is then inoculated with ferro-silicon to eliminate carbide and to insure metal will be graphitic when cast.

One source recommends that ductile base metal in the electric furnace should be heated to a minimum of 2850°F and held for ten minutes prior to tapping. It is easy to maintain close control at these temperatures in the electric furnace. This will assure a metal free of flake graphite and eliminate the risk of a poor heat.

CASTING AND FINISHING CHARACTERISTICS

Ductile iron is similar to soft, high carbon cast iron in that it has a low melting point and good fluidity in the molten state. Because of these characteristics it can be cast in intricate shapes and thin-sectioned parts. For example, the metal will flow several inches in sections as small as 1/16 in. in green sand molds at normal foundry pouring temperatures. Castings weighing but a few ounces contrast with others weighing as much as 50 tons to further verify the versatility of this new group of metals.

The machinability of ductile iron is superior to that of gray iron having the same hardness, with a considerable decrease in tearing. The millions of minute nodules of graphite provide a factor of self-lubrication which prevents galling and scuffing. It can be machined about twice as fast as steel at a considerably lower power requirement.

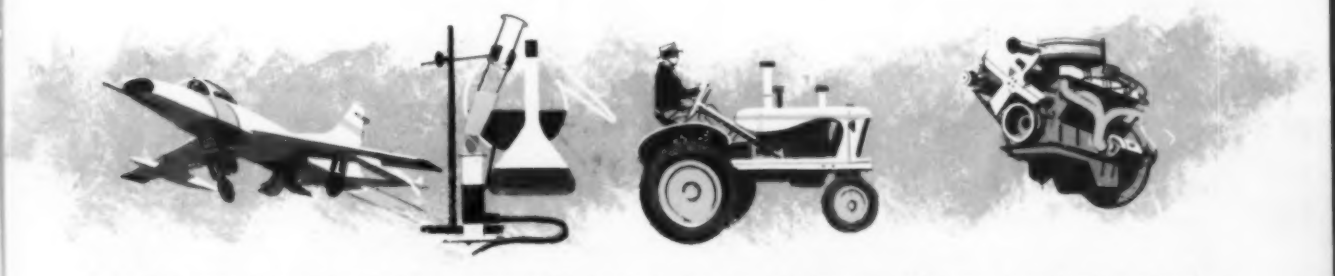
This new metal can be heat treated as readily and satisfactorily as steel. It can be softened by annealing or hardened by normalizing or oil quenching and tempering. Stress relieving of complex castings is a regular practice, while flame or induction hardening is accomplished without using special procedures, for all types except the high alloy types.

Ductile iron can be welded to itself and to other metals such as carbon steel, stainless steel, and nickel, using the same techniques as applied to good grades of gray iron. The material can also be brazed with silver or copper brazing alloys.

DUCTILE IRON APPLICATIONS

The characteristics of these irons suggest five general uses:

1. **Where greater strength or resistance to impact is needed than can be obtained with conventional cast irons.**
2. **For large castings which have been difficult to cast in malleable iron.**
3. **For replacing steel castings where higher yield strength, cost and machinability are factors.**
4. **Heat-resisting applications because of greater resistance to growth and high strength at elevated temperatures.**
5. **Pressure castings where close grain structure at low cost is a must.**



It is obvious that this development will extend the use of iron in the aeronautical, agricultural, automotive and diesel, cement, chemical processing, electrical, glass, heavy machinery, marine, mining, paper and pulp, petroleum, steel mill, tool and die, and many other industries.

The increasing use of this relatively new metal type is best proved by production figures showing that tonnages have increased approximately 100 percent in the past year.

The following listing represents most of the foundries now producing ductile iron in the electric arc furnace:

Centrifugal Casting Co., Long Beach, California
Stanley Foundries, Huntington Park, California
Farrell-Birmingham Co., Ansonia, Connecticut
Soundcast Co., Newport Beach, California
Howard Foundry Co., Chicago, Illinois
Sioux City Foundry & Boiler Co., Sioux City, Iowa
Crompton & Knowles Corp., Worcester, Massachusetts
Hunt-Spiller Mfg. Corp., Boston, Massachusetts
Baker Perkins, Inc., Saginaw, Michigan
Century Electric Co., St. Louis, Missouri
American Brake Shoe Co., Rochester, New York
Sterling Foundry Co., Wellington, Ohio
Textile Machine Works, Reading, Pennsylvania
Treadwell Engineering Co., Easton, Pennsylvania
Westinghouse Air Brake Co., Wilmerding, Pennsylvania
Westinghouse Electric Corp., Trafford, Pennsylvania
Standard Brass & Mfg. Co., Port Arthur, Texas
Fairbanks Morse & Co., Beloit, Wisconsin
Brown & Sharpe Mfg. Co., Providence, Rhode Island
Borg Warner Corp., York Division, York, Pennsylvania
Chapman Valve Co., Indian Orchard, Massachusetts
Clark Equipment Co., Buchanan, Michigan
Gleason Works, Rochester, New York
Ingersoll Rand Corp., Philipsburg, Pennsylvania
Engineering Castings Corp., Marshall, Michigan
Janney Cylinder Co., Philadelphia, Pennsylvania
Jeffrey Mfg. Co., Columbus, Ohio
Kiekhaefer Aeromarine Motors, Inc., Fond d Lac, Wisconsin
Koppers Co., Baltimore, Maryland
Penberthy Mfg. Co., Detroit, Michigan
Scott Castings Corp., Buffalo, New York
Thomas Foundries, Birmingham, Alabama
U. S. Pipe Co., Burlington, New Jersey
Wells Mfg. Co., Skokee, Illinois
Grede Foundries, Inc., Milwaukee, Wisconsin

SUMMING UP

That the uses of ductile irons are rapidly expanding there is no doubt. While it is difficult to approximate its economic impact on the producing and utilizing industries, its overall importance is now well established. There remains only a development of metallurgical refinements and production means and methods to assure its status as an equal member in our ever growing family of metals. For example, experimental work started in this country in September 1957, for adding pure magnesium to the base metal in sealed ladles. This technique . . . as well as other experimental work under way or presently planned — may point the way to greater economies in the manufacture of ductile iron.

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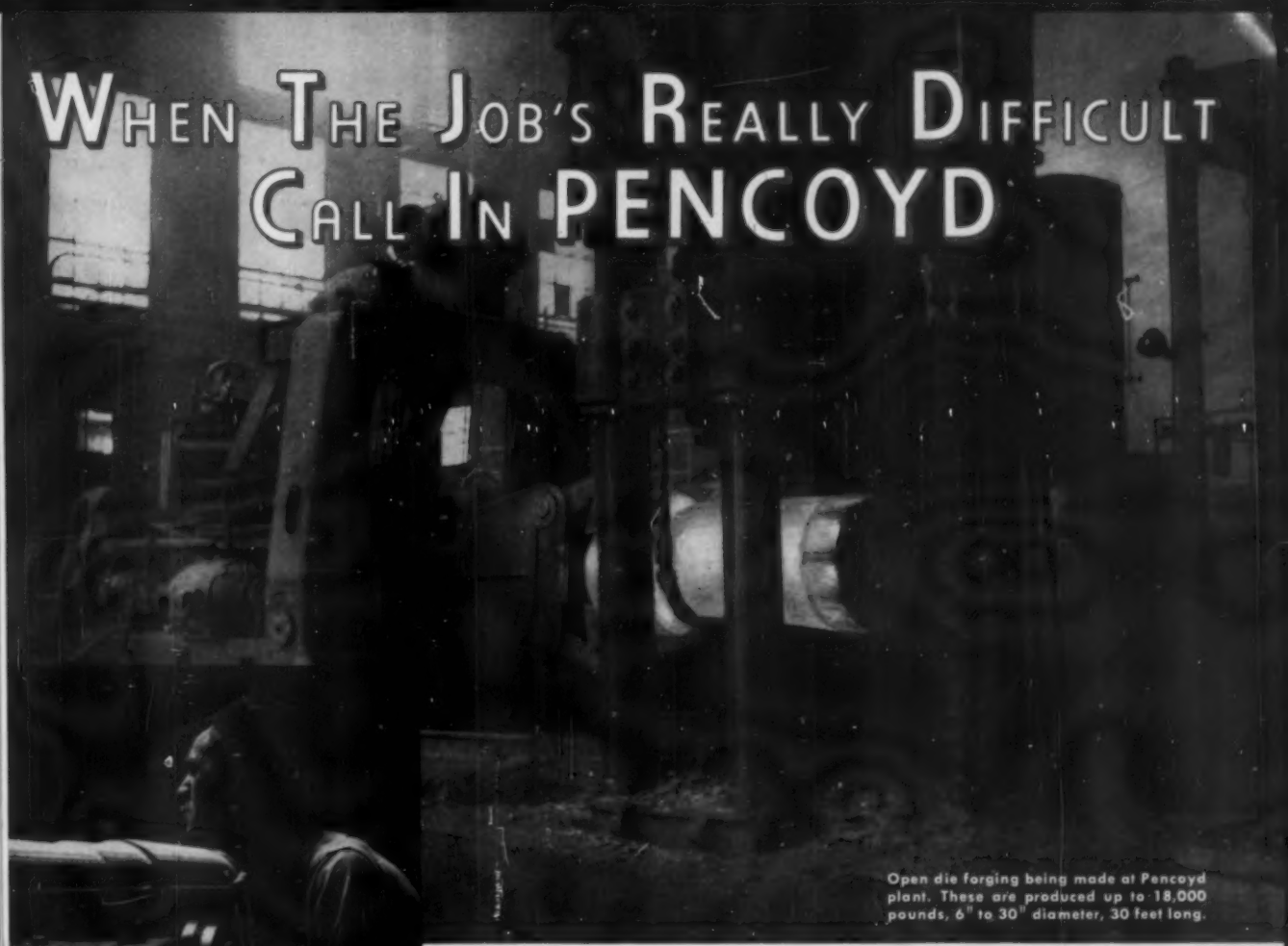
UNION CARBIDE

WHEN THE JOB'S REALLY DIFFICULT CALL IN PENCOYD



Open die forging being made at Pencoyd plant. These are produced up to 18,000 pounds, 6" to 30" diameter, 30 feet long.

In Pencoyd's machine shop. Machinist turns shaft which will be main component of a turbine. Forged alloy steel pinion forgings from Pencoyd are made to meet varied requirements.

When it comes to alloy steel forgings, Pencoyd is geared to handle the tough jobs—the ones where precise specifications require the ultimate in chemical and quality control.

One reason is Pencoyd's unique facilities. For example, Pencoyd makes its own steel simply because it provides absolute control of the quality all the way from the raw material to the finished product.

Another reason is Pencoyd's organization. Men with long years of experience in steel and forgings. At their disposal are the latest scientific and engineering developments.

This combination of modern facilities and depth of know-how is the solution to whatever forging problems you might have.

WELCOME, DELEGATES

When you're in Philadelphia you're cordially welcome to call on us. We look forward to the opportunity of having you see our manufacturing processes and meet our personnel.

A. O. Schaefer
PRESIDENT

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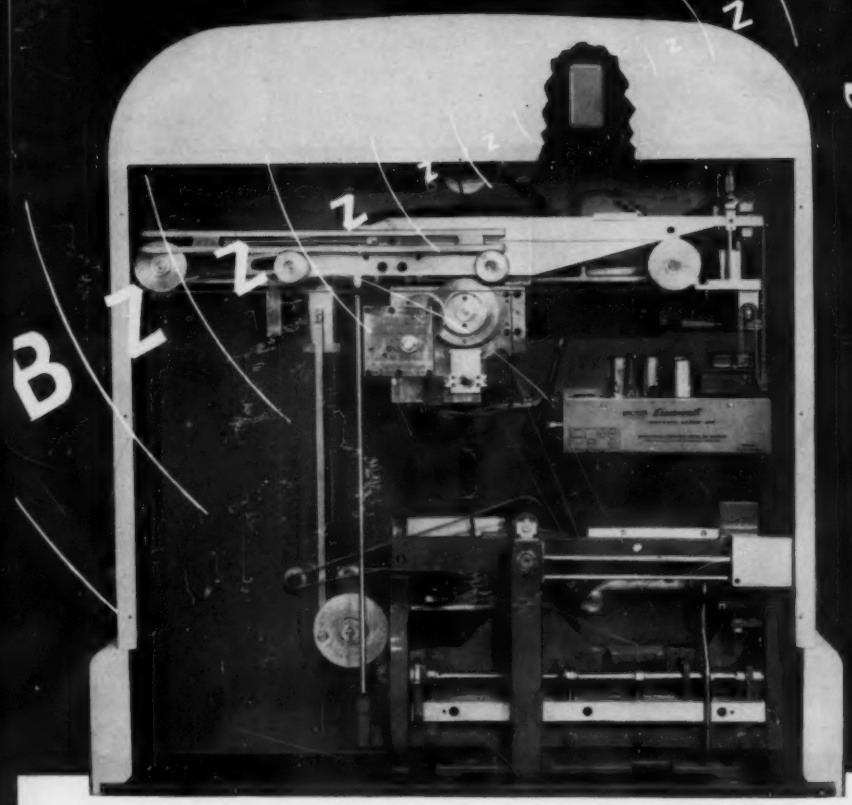

"reduce load rate application!"

A test reading taken now would probably be erroneously low — or the machine might be running dangerously overloaded.

That's why Riehle's Electro-Balanced indicating unit always *buzzes a warning when a load is being generated on the specimen at a higher rate than a servo system can follow.*

This buzz tells the operator to reduce the load rate application. It prevents wrong readings or possible machine damage. This safest and most sensitive of all indicating units is offered for both hydraulic and screw power testing machines — by Riehle. It's a Riehle feature that gives users confidence in their test results.

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APPLICATION and EQUIPMENT new products

Vacuum Furnaces

Hevi-Duty Electric Co. has announced a wide range of standard vacuum furnaces available for either single or double pump vacuums. Double pump, pit, or bell type furnaces are built to operate at tempera-

tures to 2100° F. Single pump vacuum retorts utilized in bell, pit, box or tube type furnaces may be used for applications to 1600° F. Layers of preformed and laminated insulation minimize heat losses. Water-cooled flanges perfect a vacuum seal between retort and furnace shell.

For further information circle No. 958 on literature request card, page 48-B.

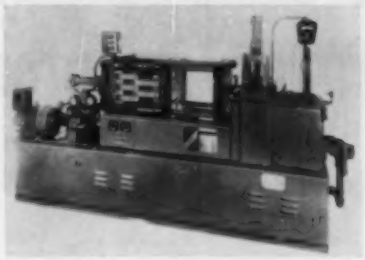
Stainless Steel

A slag-washed method of producing stainless steel free from inclusions, banding or segregation of titanium has been announced by Eastern Stainless Steel Corp. The method has been tried in one of the more complicated stainless steels, Type 321 titanium-bearing grade, and several other aircraft types. Titanium-bearing stainless steels are made in induction furnaces from selected raw materials. During the melting operation, the metal is in continuous motion due to magnetic stirring resulting from induction currents. This stirring floats oxides and other foreign substances to the top of the bath where they are removed. Prior to the teeming operation, a measured amount of a liquid slag, at 3000° F. is poured into the mold. As the molten stainless steel flows through the high-temperature slag, a washing action develops. The slag forms a protective covering over the surface preventing air oxidation. This hot slag also retards the rate of solidification, thus allowing any low density contaminants that might still remain to move into the yet unsolidified molten metal and float to the top of the ingot where they can be discarded.

For further information circle No. 959 on literature request card, page 48-B.

Die Casting

American Die Casting Machinery Co. has announced a new die casting machine that will handle shot capacities up to 4 lb. It has 150-ton locking pressure and automatic electric cycling at speeds up to 500 shots per hour. Two models are available: Model 150Z hydraulically operated plunger goose neck type for zinc, tin and lead. Model 150A cold chamber



type for aluminum, brass and magnesium. Either standard or fire-resistant fluids may be used in hydraulic unit.

For further information circle No. 960 on literature request card, page 48-B.

Oxygen Indicator

An oxygen indicator, which can measure traces of molecular oxygen in a wide range of gases, including hydrogen, nitrogen, ethylene, other hydrocarbons either saturated or unsaturated, helium, argon, and other inert gases, has been announced by Baker & Co. The new instrument has two ranges, 0 to 10 and 0 to 100 ppm. When calibrated every 8 hr., it has an accuracy of ±5% of full scale deflection. Registration of a change in oxygen concentration begins within 40 sec. and is 90% complete in 2¼ min.

For further information circle No. 961 on literature request card, page 48-B.

Blast Cleaning

Pangborn Corp. has announced a small 4-ft. Rotoblast table room for use in foundries and plants that require a small, flexible machine for a

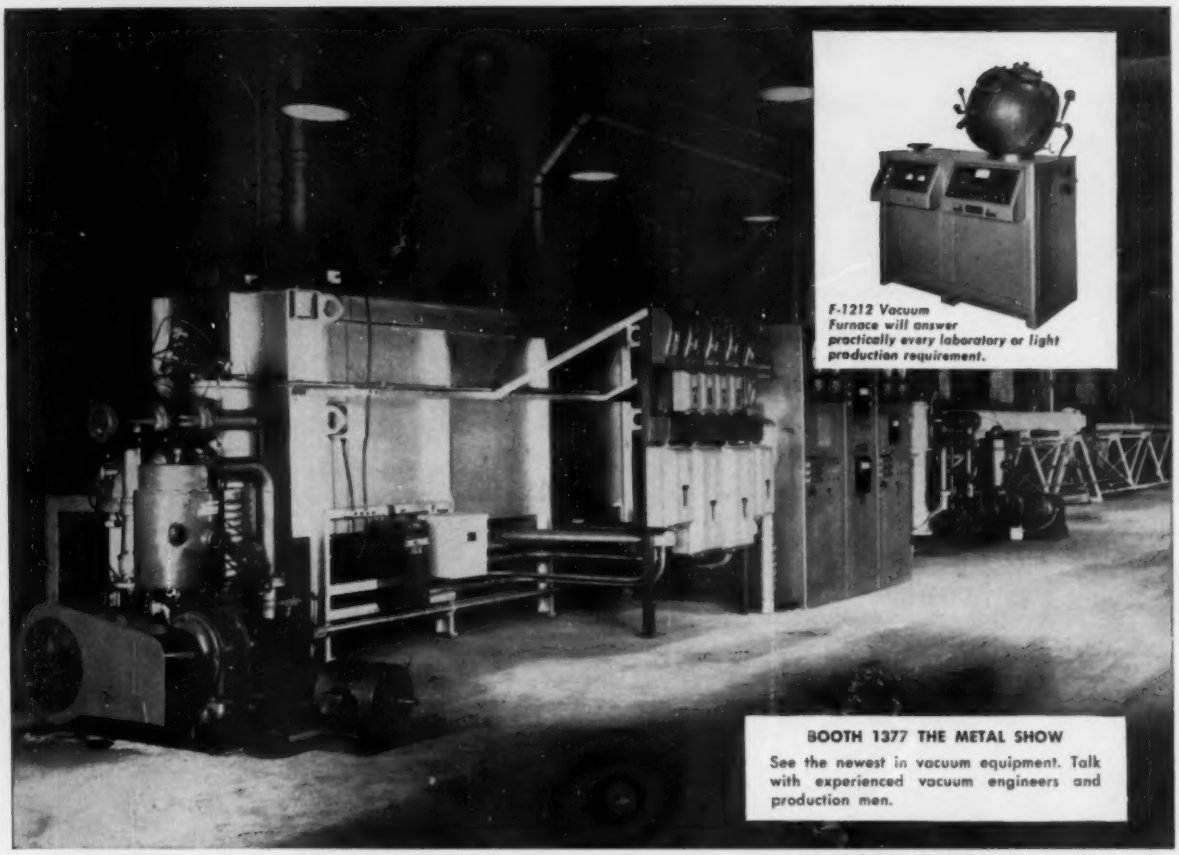
wide range of cleaning operations. Castings, forgings and stampings up to 48 in. in diameter by 24 in. high, can be blasted. This new unit is capable of blast cleaning loads weighing up to 4000 lb. A single door opens to expose half of the 48 in. diameter rotating work table. An overhead Rotoblast wheel, powered by a 10 hp. motor, will throw 15,000 lb. of abrasive per hour.

For further information circle No. 962 on literature request card, page 48-B.

Heater

Gas Appliance Service has announced a new rotor heating unit which bonds and blues rotors used in electric motors. It heats the periphery of the rotor to approximately 900° F. to separate the die-cast aluminum from the steel laminations. The heating also blues the steel laminations and causes the shaft hole of the rotor to expand sufficiently to permit insertion of the shaft, which is locked into position when the rotor is cooled. Heating time is 3 to 4 min. for a 4-in. diameter rotor. The unit consists of a rotating refractory hearth ring with rotating fixture spindles, a fur-

ATTENTION MR.


F-1212 Vacuum Furnace will answer practically every laboratory or light production requirement.
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World's largest semi-continuous high vacuum annealing furnace in operation at the Bridgeport Brass Co.

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HIVAC continues to pioneer in the vacuum field and is responsible for many of the advances in equipment designs and vacuum techniques. HIVAC offers you a wide range of reliable vacuum equipment, from small standard units such as the F-1212 Vacuum Melting and Processing Furnace . . . which will answer practically every laboratory or light production requirement . . . to special, giant-size production units such as the world's largest semi-continuous high vacuum annealing furnace designed and built for the Bridgeport Brass Company.

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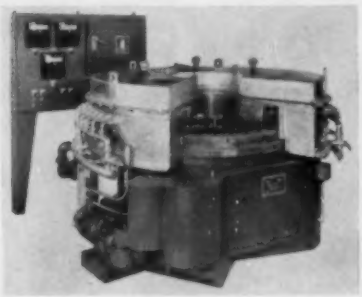
nace chamber with multiple burners in the outer periphery. The furnace chamber operates at approximately



1600° F. On 4-in. diameter rotors, production is from 350 to 400 units per hour.

For further information circle No. 963 on literature request card, page 48-B.

Test Chamber

A new temperature test chamber with 10 cu.ft. of work space has been announced by Tenney Engineering, Inc. The chamber incorporates single stage and cascade refrigeration systems with hermetic compressors and fitted with air-cooled condensers. Four

standard assemblies are offered with low temperature ranges of —40, —85, —100, and —120° F. and high temperature ranges of +240 and +350° F. Optional relative humidity could be 20 to 100% (limited by +35° F. dewpoint) and 5% at +160° F. Interior dimensions are 2 by 2 by 2½ ft.

For further information circle No. 964 on literature request card, page 48-B.

Gas Generators

A new line of inert gas generators has been announced by Thermal Research & Engineering Corp. These generators utilize direct contact cooling of the products of combustion from a high-velocity burner. Either gas or oil models are available. Multiple-burner units are offered for very large capacity requirements.

For further information circle No. 965 on literature request card, page 48-B.

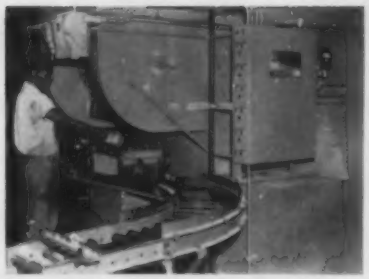
Heating Element

The Globar Div. of the Carborundum Co. has announced a new Delta silicon carbide heating element which builds up resistance at a very gradual and uniform rate. The Delta elements can be installed in a hot furnace, thus reducing downtime. They can be used in periodic or continuous applications requiring temperatures up to 2800° F. Satisfactory results are also obtained in oxidizing and protective atmospheres.

For further information circle No. 966 on literature request card, page 48-B.

Screw Parts Washer

A new washing machine which automatically washes, rinses and dries screw parts coated with quenching oil and cleans the tote pans containing the screws has been announced by Industrial Systems Co. Each loaded fixture is slowly rotated as it passes through the washing, rinsing and drying cycles. When heavier work items are processed the drum fixture is rocked instead of rotated to prevent nicking of parts. Model RJ-WRD heats by steam, is operated by one man and processes a tote pan of parts every minute at normal operating speed. The machine is adaptable for



cleaning stampings, small castings, machine and electrical parts.

For further information circle No. 967 on literature request card, page 48-B.

Automatic Loaders

A new line of automatic loaders for heat-treat furnaces, plating lines, and continuous tumbling has been announced by the Michigan Crane & Conveyor Co. The Man-O-Steel loader will deliver 500 to 5000 lb. of small stampings, screw machine parts, castings or forgings per hour.

For further information circle No. 968 on literature request card, page 48-B.

Aluminum Melting

A new line of aluminum-melting furnaces has been announced by the Industrial Furnace Div., Eclipse Fuel

Tensile Testing

Fast! Accurate! Easy!

This compact machine tests spotwelds, strip, wire, anything within its 20,000 lb. capacity. Hydraulically powered, it has an easily controlled ram, self-acting specimen grips that are open sided for easy specimen insertion. This tester, Model ST-1, is adjustable to take specimens 5" to 9" in length. Various load gauges, grips, and other modifications are available.

Write for more information – give us your requirements.

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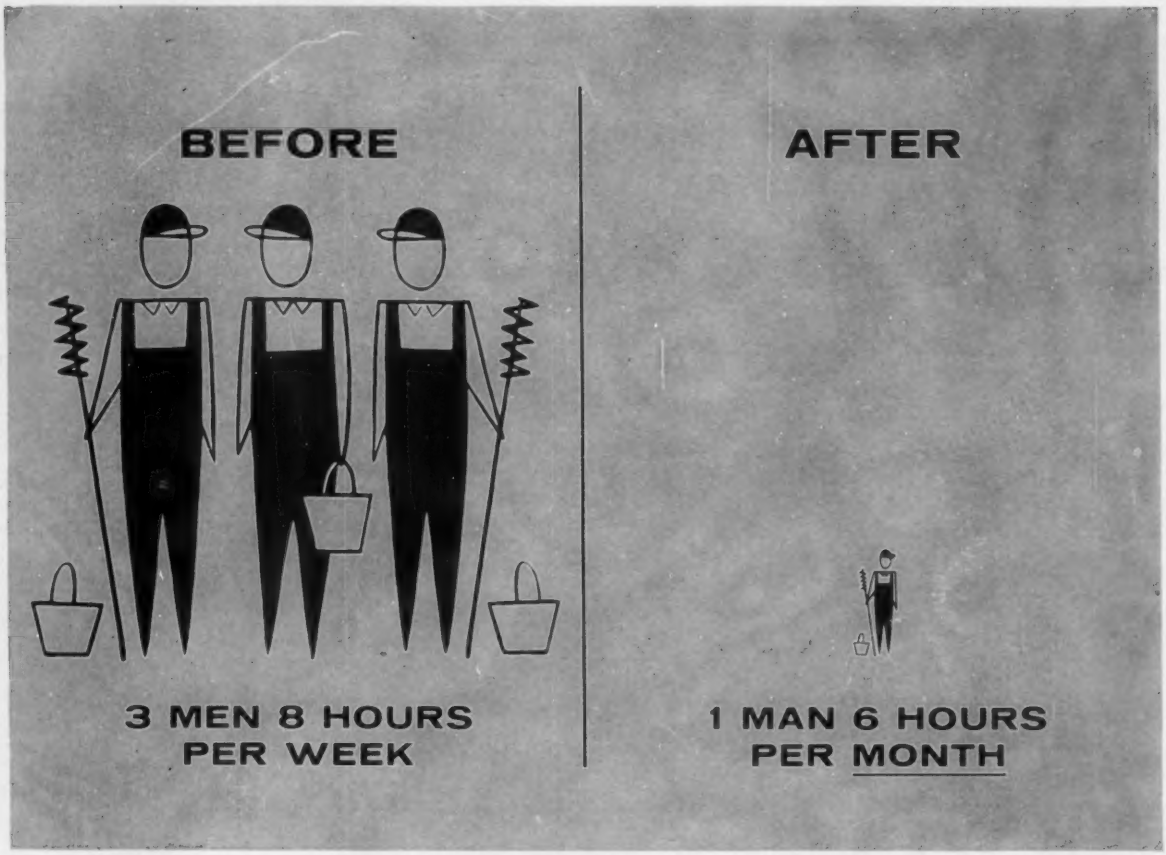

A switch to Sun Quenching Oil Light resulted in this dramatic reduction in cooler-maintenance man-hours in a major automotive plant.

SWITCH TO SUN QUENCHING OIL LIGHT CUTS COOLER MAINTENANCE BY 94%

After switching to Sun Quenching Oil Light, a leading auto manufacturer reported a *94% reduction in cooler maintenance.* No heavy sludge deposit had formed on cooler coils after 18 months of continuous use. It took *fewer* men *far less time* to clean coolers.

Reason: Sun Quenching Oil Light has natural detergency and solvent action that *keeps cooling systems clean for long periods.*

It's Versatile. Sun Quenching Oil Light can be used in any type of quenching-oil system. It has uniform quenching properties and low drag-out.

It's Economical. Sun Quenching Oil Light can save you money two ways . . . in low initial cost and in reduced maintenance.

For Full Information, call your Sun representative or write to SUN OIL COMPANY, Philadelphia 3, Pa. Dept. MP-10.

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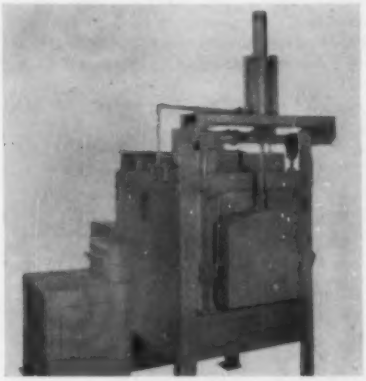
Engineering Co. They are available for gas, oil, or combination firing, with burners mounted in the arch



or roof for firing down into both melting and holding chambers. A total of 16 combinations of sizes and dip-out arrangements are available. Hourly capacities range from 300 to 2000 lb.

For further information circle No. 969 on literature request card, page 48-B.

High-Temperature Testing

Instron Engineering Corp. has announced equipment for tensile testing at temperatures up to 2200° F. at a tensile force of more than 1500 lb.

A controller panel regulates temperatures within the furnace to within ±2° F. A dual furnace arrangement can be installed for added versatility and speed of testing.

For further information circle No. 970 on literature request card, page 48-B.

Silicon Iron

A new silicon iron sheet material designed to increase the efficiency of transformers, motors and generators has been announced by the General Electric Research Laboratory. The new doubly-oriented magnetic sheet material can be magnetized in four directions and made in a wide range of thicknesses. A different kind of grain alignment (technically referred to as "cube texture") gives magnetic properties not only back and forth along the sheet but also back and forth across the sheet. Rigid control of the internal structure of the metal during all steps of processing, from the original casting through successive heat-treating and rolling-mill operations is maintained. The basic raw material is a form of silicon iron similar to the typical "soft" magnetic sheet used in transformers and motors.

For further information circle No. 971 on literature request card, page 48-B.

Laboratory Ware

A new high-alumina jar has been announced by McDanel Refractory Porcelain Co. The laboratory jar has

a 96% Al_2O_3 body with a MOHS hardness of 9. It has bronze hardware and rubber or neoprene gaskets.

For further information circle No. 972 on literature request card, page 48-B.

Laboratory Rolling Mills

Heavy duty, high precision 2-high/4-high combination rolling mills for use in ferrous and non-ferrous metals laboratories and pilot plants have been announced by Loma Machine Mfg. Co. Designed for processing high temperature superalloys, nuclear fuels, stainless steels and refractory

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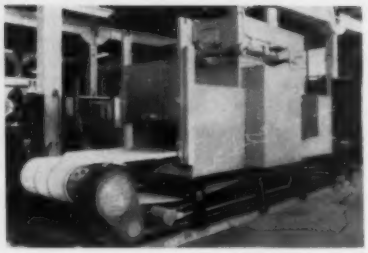
metals, the mills have high separating force and torque transmission capacities. They are currently available in backup roll diameters from 6 to 15 in., in work roll diameters from ¾ to 5 in., and in face widths up to 24 in.
For further information circle No. 973 on literature request card, page 48-B.

Conveyor Oven

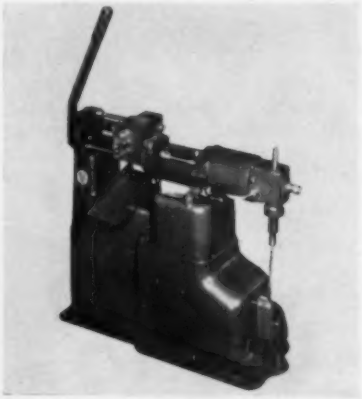
Grieve-Hendry Co. has announced an oven with a conveyor belt which carries the product through the heated zone and can be arranged for both automatic loading and unloading facilities. The unit illustrated is gas



fired, with a 1,000,000 Btu. burner and a maximum temperature of 450° F. The continuous belt is 36 in. wide and is driven by an electric motor. Speed of belt is adjustable from 2 to 10 ft. per min. Inside dimensions of baking chamber of the oven are 38 in. by 24 in. by 15 ft. Ovens can be made for heating by gas, electric or steam.
For further information circle No. 974 on literature request card, page 48-B.

Die Casting Machine

A small aluminum cold chamber die casting machine has been announced by British Machines & Foundry Supplies, Ltd. This machine will cast aluminum alloys up to its capacity of 2½ oz. per shot and will cast up to 200 parts per hour. The DCMT Rotor-

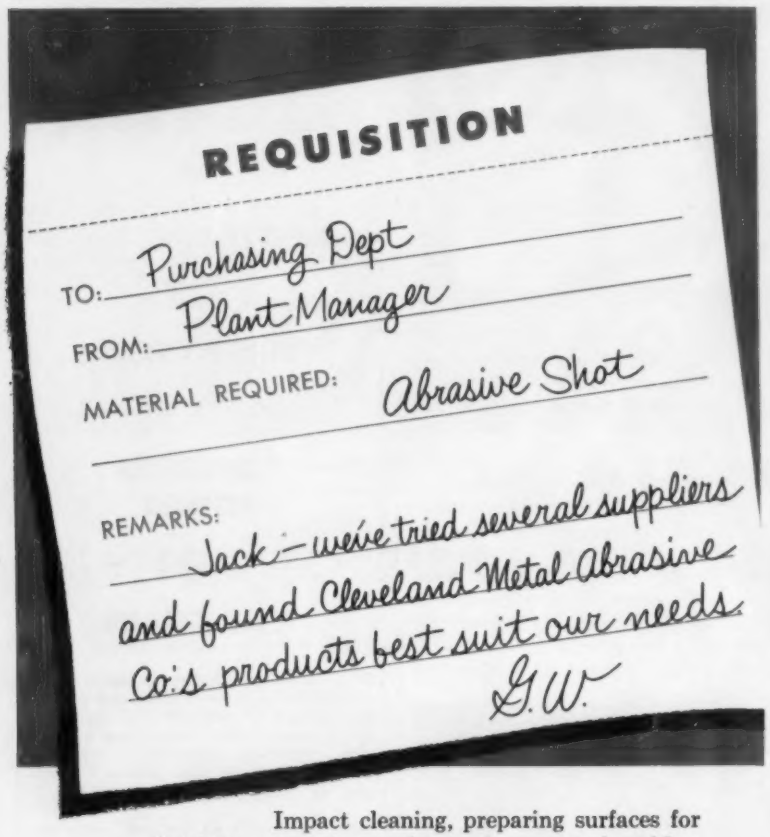


caster has an air-operated impact-type injection system and a hand-operated toggle mechanism which opens and closes the die, thereby permitting operator to insert the stacked laminations into the cavity.
For further information circle No. 975 on literature request card, page 48-B.

Cutting Titanium

A portable nibbler that will cut titanium, stainless and all types of nonferrous metals without distortion has been announced by Fenway Machine Co. The tool cuts up to 55 in.

per min. with a minimum radius of 6 in. but for a shorter 3 in. radius, a special die holder is available for use on 12 gage stainless and lighter metal.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Jack – we've tried several suppliers and found Cleveland Metal Abrasive Co.'s products best suit our needs.
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Weighing only 13 lb. and measuring only 13 in. in length, the HN nibbler operates on a.c. or d.c., 115 volts, 60 cycles.

For further information circle No. 976 on literature request card, page 48-B.

High-Vacuum Pump

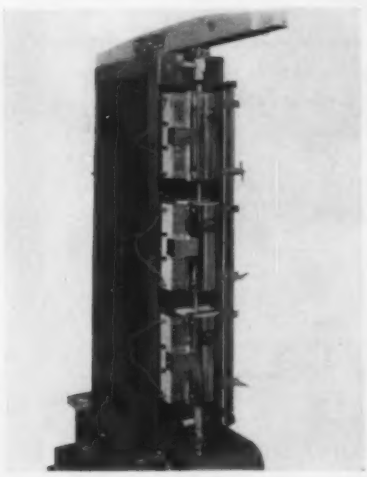
A new high-vacuum pump has been announced by Rochester Div. of Consolidated Electrodynamics Corp. It provides an electronic method for producing high vacuum without the use of organic pump fluids. The Evapor-Ion pump creates a dry vacuum in the range from 10^{-4} to 10^{-9} mm Hg. It pumps active gases by the gettering action of evaporated titanium wire, and pumps inert gases by ionizing and burying them under a layer of titanium. Pumping speed is 1900 liters

per sec. for nitrogen, 1000 liters per sec. for oxygen, and 3000 liters per sec. for hydrogen.

For further information circle No. 977 on literature request card, page 48-B.

Creep Testing

Creep testers for seasoning titanium specimens are now being furnished to customers' specifications according to Riehle Testing Machines.



The new creep testers incorporate electric furnaces arranged in tandem so three titanium specimens can be seasoned at one time.

For further information circle No. 978 on literature request card, page 48-B.

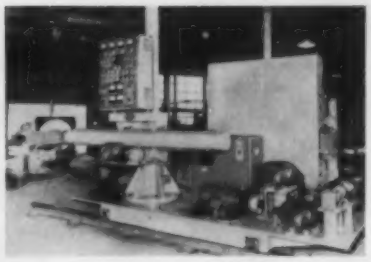
Vanadium Oxide

A new grade of fused vanadium oxide (V_2O_5) with a nominal purity of 98% has been announced by Electro Metallurgical Co. A typical analysis for a new grade is 98% vanadium oxide, 1 to 2% alkali oxides, maximum 0.05% sulphur and maximum 0.2% insolubles. The low alkali-oxide content is significant in ferrous applications and the reduced insolubles content will aid in the manufacture of nonferrous alloys.

For further information circle No. 979 on literature request card, page 48-B.

Welding Manipulator

The C. B. Herrick Mfg. Corp. has announced a new ram-type welding manipulator. Electronic control of all ram machine movements plus independent and simultaneous control of both heads are featured. Arc start and stop, wire inch up and down, current raise and lower, flux feed and shut off are also controlled. All controls, plus speed tachometers and welder meters are in the pendant box. Everything rides on the carriage. Welding may be performed with ram travel or track travel.



For further information circle No. 980 on literature request card, page 48-B.

Power Presses

A new series of air or hydraulic, desk-type production presses for precision straightening, assembling, and cold riveting has been announced by General Manufacturing Co. The horizontal design of these 10 and 20 ton presses permits hand or automatic loading and unloading, particularly from overhead. Parts to be straightened are held in manual or air operated centers or rollers while constant reading underside indicators show the amount of distortion and deflection

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Vapor Blast Liquid Honing is the *original* liquid abrasive surface conditioning process developed and perfected by the Vapor Blast Mfg. Co. It has proved itself in finishing, cleaning, descaling and deburring operations in scores of industries and many hundreds of plants.

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Twenty-five years ago Northwest Chemical Company was founded with the express idea of supplying BETTER cleaners to the trade. Today, thanks to a steadfast adherence to the policy of top quality ingredients carefully blended with mature experience and pleasingly flavored with good service, Northwest has attained a position of respected leadership in the cleaner field.

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9310 ROSELAWN DETROIT 4, MICH.

pioneers in pH cleaning control *serving you since '32*

necessary. Pressure is applied where needed through a single head on a rolling carriage or through multiple heads adjusted longitudinally to meet requirements.

For further information circle No. 981 on literature request card, page 48-B.

Melting Furnace

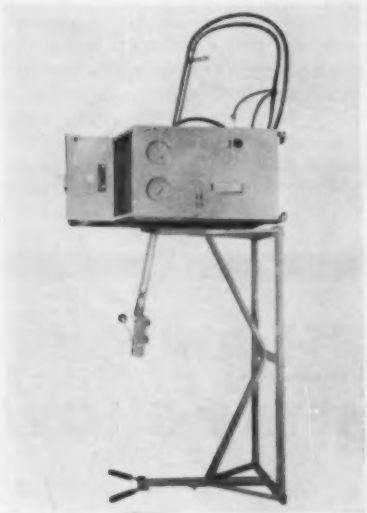
A new 50-lb. vacuum melting furnace has been announced by Hoskins Mfg. Co. The furnace includes most of the accessories normally found on 1000 or 2000 lb. production vacuum

furnaces. It is capable of melting and pouring four 50-lb. heats without breaking the vacuum. The unit is being used to determine whether electrical resistance and resistor alloys can be improved through vacuum melting, and to carry out experimental work with new alloys.

For further information circle No. 982 on literature request card, page 48-B.

Abrasive Blasting

A pressure blast wet blast unit, designed for the blending of cracks and flaws on the interior leading and trailing edges of propeller blades, has been announced by Cro-Plate Co. It was adapted from a standard 30 by 30 in. hand cabinet. The angle iron frame work to the left of the cabinet supports the blade in a tilted position with the open hub end inserted into the cabinet so that the wet abrasive slurry emitted by the blast gun may be recirculated through the blast system. The operator takes his position at the right of the unit and manually inserts the gun lance into the interior of the blade. Fibre wheels, spring loaded, on the gun head guide the lance maintaining the direction and distance of blast from the three small nozzles mounted in parallel.



For further information circle No. 983 on literature request card, page 48-B.

Stainless Plate

Armco 17-4 PH stainless steel plate has been announced by G. O. Carlson, Inc. To produce this 3950-lb. plate, it is necessary to maintain a near-constant temperature from the time the ingot is poured through the slabbing operation. Plate measures 174 by 79 by 1 in. 17-4 PH plate has the mechanical properties of the hardenable

chromium types and a workability and corrosion resistance approaching Type 302 or Type 304 stainless steels.

For further information circle No. 984 on literature request card, page 48-B.

Temperature Reading

W. C. Dillon and Co. has announced a new straight form thermometer. An adjustable mounting nut makes it possible to turn and lock the head in position for maximum visibility. These instruments are made in both 3 and 5 in. head sizes and can be supplied in stem lengths of from 2½ to 72 in. Ten different ranges are available.

For further information circle No. 985 on literature request card, page 48-B.

Vacuum Heat Treating

A vacuum heat treating furnace which operates at 700 to 2150° F. at a vacuum of 0.1 micron has been announced by C. I. Hayes. The furnace uses a heating element of new design which operates at low voltage. Baffles

Fast-accurate

SULFUR

analysis

IRON · STEEL · PETROLEUM PRODUCTS · ORGANIC CHEMICALS · STAINLESS ALLOYS · COAL · WOOD · NON-FERROUS METALS · MINERALS · COKE

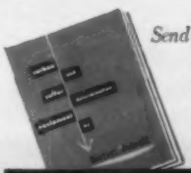
with a

DIETERT-DETROIT

Sulfur Determinator

The Dietert-Detroit Sulfur Determinator features an extremely simple direct-reading burette. No involved measuring or computing. Provides fast accurate analysis of sulfur content in scores of materials. Low cost, durable, easily maintained. Widely used in company laboratories and institutions of every description for over 18 years.

Dietert-Detroit Sulfur Determinator No. 3104, with combustion Furnace.



Send for FREE Catalog!

16 page Dietert-Detroit Catalog illustrates and describes both Sulfur and Carbon Determinators and complete line of accessory equipment and supplies.

HARRY W. DIETERT CO.
CONTROL EQUIPMENT
9330 ROSELAWN · DETROIT 4, MICHIGAN

Send me your latest Carbon-Sulfur Determinator catalog.

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COMPANY_____

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CINCINNATI PRECISION IS TAILORED* TO

At the Metal Show see the INDUCTRON

simultaneously hardening both ends of Chrysler push rods. Rods are 5/16" x 11.58", SAE 1056 steel. Special fixture feeds rods through work coils into oil quench.

all new inductron

INDUCTION HARDENING MACHINE

Cincinnati's new Inductron® offers more advantages in performance, flexibility, ease of operation, and reliability of component life than any similar equipment previously offered to industry. Built in 15, 30 and 50 KW capacities, these machines operate at frequencies up to approx. 1000 KC for faster heating, thinner case, greater freedom from scale and distortion.

All units are wired and equipped to operate on either voltage, 220/440. Power, in the smoothest form of d.c. possible, is adjustable over the entire range, using only a basic rectifier circuit with low-cost, long-life rectifier tubes. The standard Inductron has a manually adjustable output transformer to accommodate a wide range of workpieces. A self-contained, externally variable output RF transformer can be provided at extra cost. The feed back (grid drive) system is self-regulating and requires no adjustment when changing work coils or transformer position, over the entire power range.

Many more design advantages—in component and circuitry construction, in controls and instruments—are incorporated. Throughout, the new Cincinnati Inductron assures you highest operating efficiency with maximum component life.

***BUILDING BLOCK CONSTRUCTION**

CINCINNATI

flamatic and inductron *hardening machines*

in Action at the **METAL SHOW**

SELECTIVE HEAT TREATING YOUR REQUIREMENTS!

all new flamatic

FLAME HARDENING MACHINE

High machine flexibility for the flame hardening of an even wider range and diversity of parts . . . *at greater-than-ever-economies* . . . is the keynote of this new Cincinnati Flamatic®.

The standard machine is built with a functional, flat bed design—having large, open area—on which any one of a wide variety of tooling and work-handling systems can be located. Thus the basic machine becomes highly adaptable to a large range of work that previously fell in the "special or modified-standard" machine class.

Other provisions include precision electronic temperature control system; compact, all-inclusive control cabinet; integral quench tank with high-capacity heat exchanger, quench agitation system, and large discharge conveyor that integrates with plant conveyor systems.

As before, Flamatic gives you a wide choice of fuel gas, easy set-up and operation, automatic heating to pre-set temperature, uniform results, with top calibre construction that provides the utmost in freedom from downtime.

When you have parts requiring selective surface hardening or other heat processing, you'll profit by talking to Cincinnati . . . builders of *both* flame and induction hardening machines. Call in a Process Machinery Division field engineer. He is ideally equipped to evaluate your needs and give you unbiased recommendations as to the most economical and efficient equipment for your work.

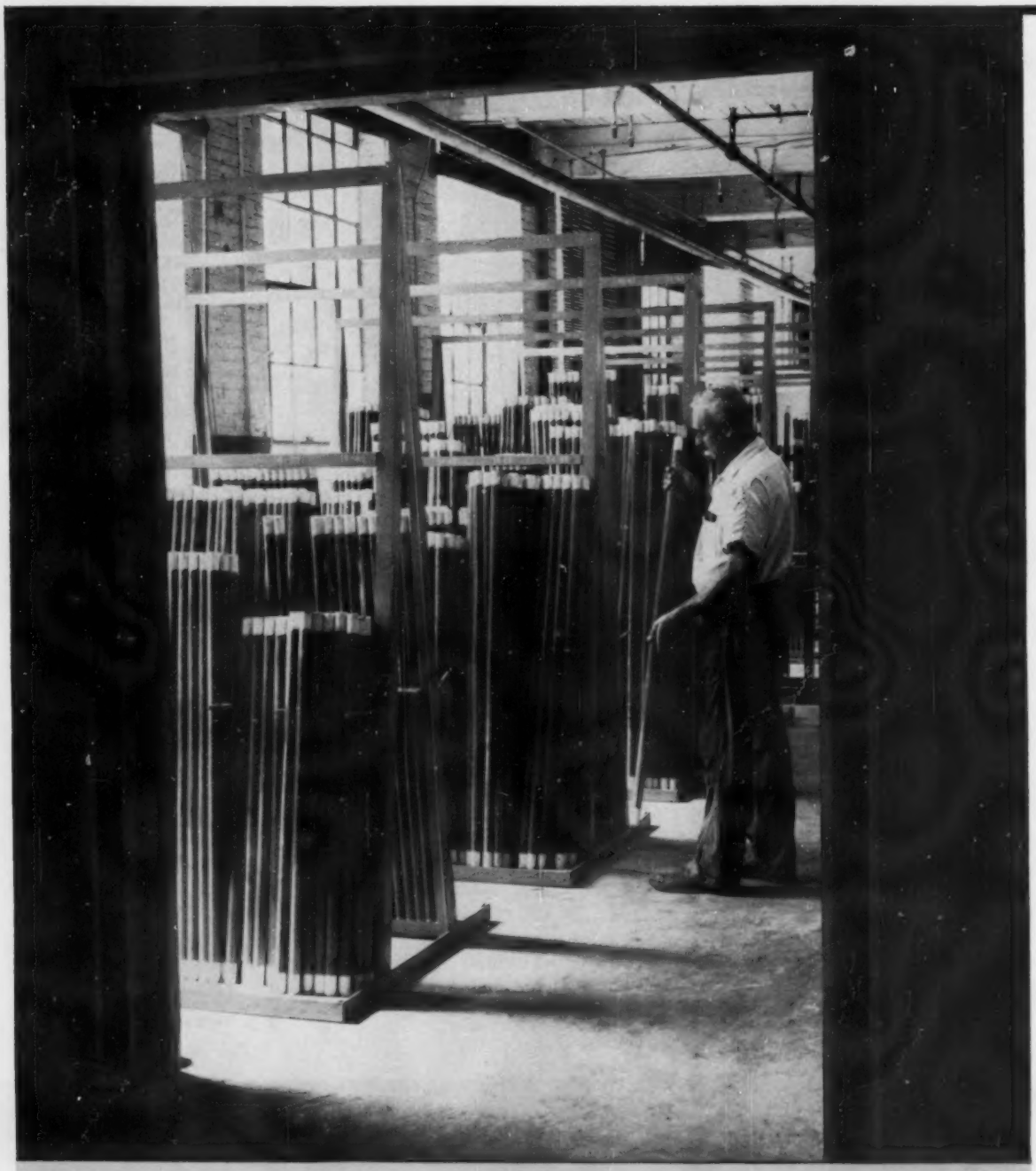
At the Metal Show see the FLAMATIC

simultaneously spot hardening both cup and pad sections of automotive rocker arms, six parts at a time . . . a typical adaptation of the standard unit. Part material is nodular iron. Timed cycle is automatic, except for loading of the fixture.

BOOTH NO. 1798
CHICAGO AMPHITHEATRE
NOV. 4-8

PROCESS MACHINERY DIVISION
THE CINCINNATI MILLING MACHINE CO.
CINCINNATI 9, OHIO, U. S. A.

One-Piece "HOT RODS" now



Large Stocks of One-Piece Elements. You get quick deliveries of Norton "Hot Rods" — on short notice. Also, most popular sizes of these CRYSTOLON heating elements — like the sizes shown in this section of the Worcester stockroom — are now made in the new, one-piece construction — with no welds. This assures greater strength and uniform straightness throughout each rod.

ready for immediate delivery

famous for Long Life and Economy

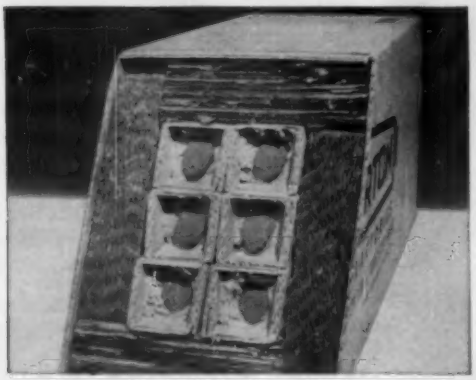
CRYSTOLON* heating elements bring you extra advantages for better performance and bigger savings.

"Hot Rods" are a typical Norton ℞ — an expertly engineered prescription for greater efficiency and economy in electric furnaces and kilns. Made of self-bonded silicon carbide, each rod has a central hot zone and cold ends. Most popular sizes are non-welded and interchangeable with your present rods.

You save in element costs because you use far less "Hot Rods". Also, their more uniform heating quality, due to their slow, evenly matched rate of resistance increase, helps you protect product quality and maintain a smooth production flow. For further facts on "Hot Rod" advantages send for booklet *Norton Heating Elements*, NORTON COMPANY, Refractories Division, 329 New Bond Street, Worcester 6, Massachusetts.

Greatly Increased Strength. Ever since they were first produced "Hot Rods" have been endorsed by users for outlasting other non-metallic heating elements *up to 3 to 1*. Today, the new one-piece rod, made in most popular sizes — and soon available in all sizes — is twice as strong in standard cross-bending tests.

Straighter Than Ever. Looking down the entire length of a one-piece, non-welded "Hot Rod" you'll note there isn't the slightest bulge in the surface. So, when you insert them into the openings of your furnace or kiln you can be sure there'll be no binding due to uneven diameters.

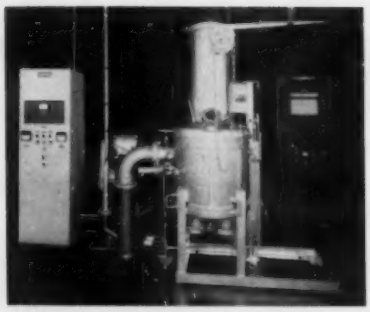


Scientifically Safe Packaging. Here, a carton of "Hot Rods" has been cut in half to show you how our scientific packaging protects them even more thoroughly than delicate household glassware or china. They're packed shockproof to reach you unbroken.

*Trade-Mark Reg. U.S. Pat. Off. and Foreign Countries

NORTON
REFRACTORIES
Engineered... ℞ ...Prescribed
Making better products . . . to make your products better

NORTON PRODUCTS
Abrasives • Grinding Wheels • Grinding Machines • Refractories
BEHR-MANNING DIVISION
Coated Abrasives • Sharpening Stones • Behr-cat Tapes



have been eliminated from inside the unit and the inner chamber is of nickel-clad steel. An hydraulic lift raises unit head (and integral cooling chamber) to facilitate work handling.

For further information circle No. 986 on literature request card, page 48-B.

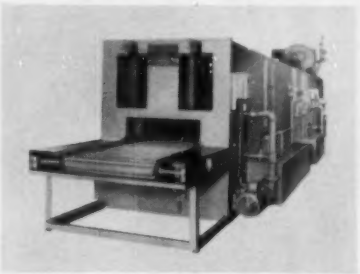
Acid Inhibitor

Enthone, Inc. has announced a new inhibitor for use in acid solutions. It can be used on high carbon steel without the danger of etching. It is used at a concentration of about 0.2% by volume and can be added to cold or hot sulphuric or muriatic acids, or to other nonoxidizing acids such as phosphoric, hydrofluoric, oxalic and citric acids.

For further information circle No. 987 on literature request card, page 48-B.

Parts Washing

A new automatic washing machine that provides for all cleaning operations in one central area has been announced by the Alvey-Ferguson Co. Two overhead conveyors and a flat-wire mesh-belt conveyor pass through the machine, which incorporates an automatically timed wash-rinse-dry cycle. The three conveyors may be

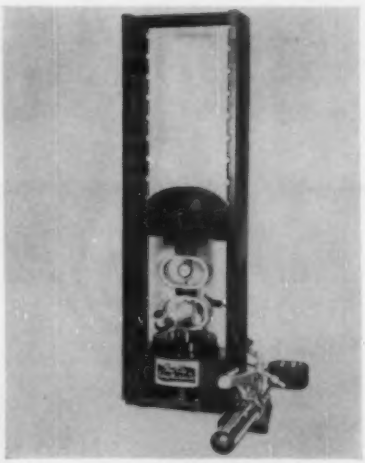


operated either simultaneously or individually as required. Common solution tanks and spray system are used for all three conveyor lines.

For further information circle No. 988 on literature request card, page 48-B.

Compression Tester

Steel City Testing Machines has announced a new portable, hydraulically operated machine for quick compression testing. This unit has a capacity of 150,000 lb. The overall weight of the tester is approximately 170 lb. Any vertical dimension between 9½ and 32 in. may be obtained. Width between uprights is 11 in. The compressive force is provided by means of a hand operated pump which incorporates its own oil reservoir. A piston stroke of 1½ in. is standard on this unit.



For further information circle No. 989 on literature request card, page 48-B.

Calculating Machine

A calculating machine that weighs only 8 oz. will be shown at the National Metal Exposition, Nov. 4 to 8, by Utility Supply. The Curta calculator can add, subtract, multiply, divide, square, cube, extract the square root.

For further information circle No. 990 on literature request card, page 48-B.

Metal Cleaning Control

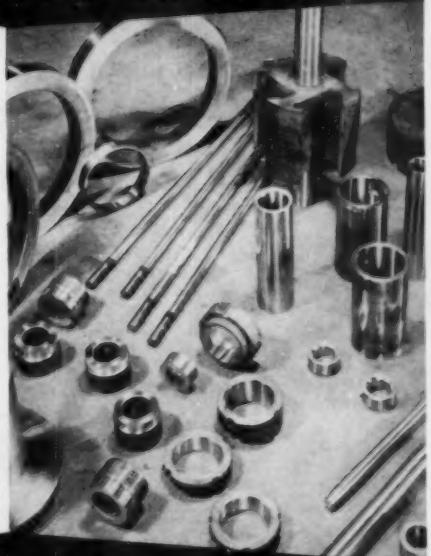
An addition agent to replace the sodium hydrosulphite in metal cleaning and copper cyanide baths has been announced by Northwest Chemical Co. Alkontrol reduces the hexavalent forms of chrome contamination to harmless ones. When used in a cop-

Wear, Corrosion And Heat Resistant Welded HARD-FACED Components Produced To Specifications

■ Whenever your product requires special components with superior wear qualities, precision surface finish that provides dependable long life service under severe operating conditions, specify Cleveland Hard Facing.

As specialists in the application of welded hard facing metal overlays, we are completely equipped and qualified to economically produce hard faced components to meet your specifications. For practical assistance on your application, call on one of our specialists.

Write for detailed literature.



Application Specialists Of Wear, Corrosion And Heat Resistant Overlays

Cleveland Hard Facing, Inc.

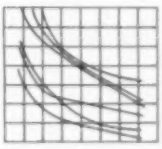
3047 Stillson Avenue • Cleveland 5, Ohio

It isn't easy . . . the job of knowing exactly the right way to apply heat in the making of your product. That's what we're here for, to give you the right answers. Stay with us for five minutes and four pages and we'll give you an idea how Lindberg's answers can ease your job.

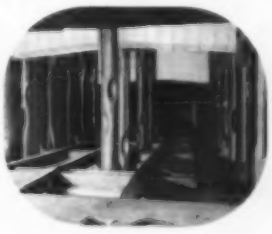
Applying heat to industry has been Lindberg's business for many years. But the way we've gone about our business is what's most important to you. First of all, Lindberg covers all phases of "heat for industry" in a much broader way than anyone we know in the field. So we can recommend just the right equipment, the correct techniques best suited to your individual requirements and your production methods. It's pretty significant, too, that over the years Lindberg has come up with many of the most vital improvements in the industry, frequently as an answer to customer needs for faster, more efficient, more economical methods.

We've kept ahead of the field because here at Lindberg we have been able to put together an exceptional creative staff of metallurgists, research technicians and engineers, the best in the business, we vow. Also, through our world-wide organization, with plants and subsidiary companies in many countries, we are always abreast of the latest industrial developments anywhere.

Here are a few examples of Lindberg innovations. Years ago Lindberg engineers pioneered and developed the famous Cyclone furnace, applying the first 100% forced convection heating principle for accurate, low cost tempering. This was followed by the introduction of the world's first high temperature (2200° F.) endothermic generator and the raising of 100% high speed convection heating into the high temperature field.



Modern heat treating methods owe much to Lindberg, what with the development of controlled atmosphere generators, the creation of dew point equilibrium curves to establish proper atmosphere values for type of steel and temperatures involved and the exclusive Lindberg Carbotrol to maintain these values automatically. For fuel-fired atmosphere furnaces we also perfected the "dimple" vertical radiant tube, a big step toward better furnace design. Provides more efficient heat application in more compact, less space-consuming furnaces. Portable, replaceable in a few minutes, this tube operates at maximum efficiency longer.



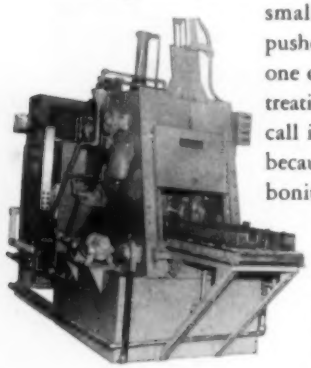
Lindberg Engineering Company

2450 WEST HUBBARD STREET • CHICAGO 12

Scratch a new industrial heating idea and you'll find "Lindberg" every time. Our research and development engineers and technicians won't have it any other way. That's why they consistently come up with newer and better ways of making heat work for you in your industry, bless 'em.

You've probably heard a lot about Lindberg's wonderful new CORRTHERM electric heating element lately. It's quite a thing! It makes carbonitriding and carburizing with electricity practical, efficient and economical. CORRTHERM elements operate at extremely low voltage, eliminating leakage through carbon saturation, previously such a problem in electric atmosphere furnaces. With superlative heating units for either electric or fuel-fired furnaces you can be sure that Lindberg need play no favorite when recommending the equipment most practical, most efficient and most economical for your job.

Our name is synonymous with carbonitriding and carburizing furnaces. We've built thousands of them, from small jobs up to big three-row pusher automatics. At the left is one of the most widely used heat treating furnaces in the world. We call it Lindberg's "Five-in-one" because it's ideal for five jobs, carbonitriding, carburizing, annealing, hardening and carbon restoration. Our Heat Treating Furnace Division has the experience, the knowledge and the courage to engineer and build furnaces to meet the precision requirements of any heat treating operation. We build them for carbonitriding, carburizing, hardening, tempering, normalizing, bright stainless annealing, brazing, carbon correction, nitriding, sintering, or what need you. Atmosphere generators, too, all types of them to take care of any heat treating operation requiring a protective atmosphere.

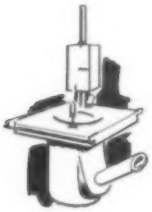


For research use Lindberg makes a broad line of heating equipment scientifically designed for maximum control and dependable operation, everything from simple hot plates to small heat treating furnaces actually usable for minor production jobs. An unusual Lindberg development for laboratory use is a High Frequency unit for carbon and sulfur determination.

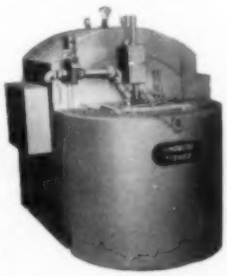
New at Lindberg is a line of larger-than-lab, smaller-than-standard equipment designed specifically for pilot plant use. You can test your materials, your methods, on equipment moderately priced but production capable. Fuel-fired, electric and High Frequency units are included. At the right is an electric vacuum-type furnace ideal for testing this newest and most promising heat treating method. For complete details write our Pilot Plant Equipment Division.

From a laboratory furnace no bigger than a breadbox to a car bottom furnace as big as a six-room house, there's no limit to what Lindberg can make heat do for you. Whatever product you make, if heat will make it better, there's a Lindberg furnace that's sure to do the job better.

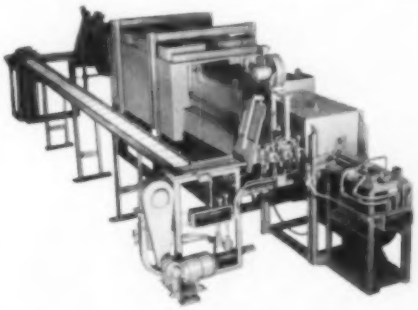
Heat and aluminum have been Lindberg's twin babies for years. Our research and engineering staff has made a lot of innovations in this field, too, starting with the now famous two-chamber induction melting furnace introduced more than ten years ago. Most recent development is the Autoladle (we call it "Little Joe"), the first practical automatic aluminum ladling unit yet devised. Used with Lindberg melting and holding furnaces "Little Joe" makes automatic casting of aluminum fast, dependable and economical.



Lindberg's Melting Furnace Division makes a wide variety of melting and holding furnaces for aluminum, brass, bronze, tin, zinc, lead and other non-ferrous metals. These include aluminum reverbs, nose-pouring crucibles, electric resistance holding furnaces (illustrated at the right complete with "Little Joe" automatic ladling pump). For foundry, permanent mold or die-casting plant, independent or captive, there are Lindberg melting and holding furnaces to fit your requirements. If your problem in this field needs a special solution Lindberg's design staff can find it.



Suppose your industrial heating operation has to do with ceramics. We also offer you superior equipment for every ceramic application. Lindberg's long experience in applying heat and atmospheres to metals has been a natural background for the development of ceramic kilns for all purposes. Our Ceramic Kiln Division provides all types of kilns, big ones, small ones, electric or fuel-fired, standard or special, for electrical ceramics, abrasives, refractories, ferrites, sintering and



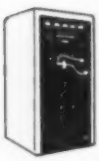
calcining, structural clay products and white ware. Shown above is an entirely new type of kiln, developed for the special requirements of electrical ceramics. It is completely automatic, atmosphere controlled with five zones of control for flexibility. In ceramics, too, our designers and engineers welcome the opportunity to develop special equipment to fit your special product requirement.

heat for industry

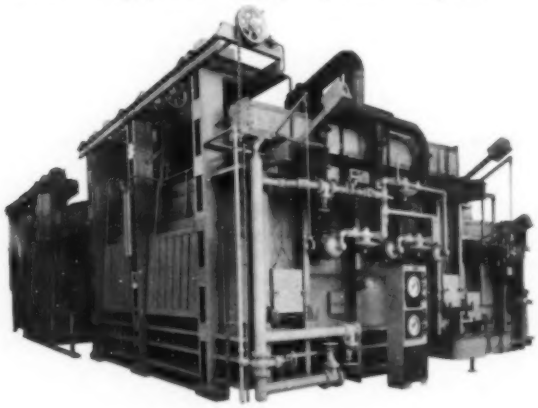
Bring all your questions to Lindberg at the Metal Show in Chicago. It's 9 to 1 our eggheads can answer them. Just look for "Lindberg" and "Booth 620". You'll find all the smiling faces there . . . in the low-pressure area. A cordial invitation, too, to visit our Chicago plant.

To round out the full measure of its service to "heat for industry" Lindberg is one of the largest makers of High Frequency heating units. Our "H-F" designers and engineers have made outstanding developments in this important heat treating field. For example, at the right is a remarkable unit just recently completed for aluminizing automotive valves. It was designed vertically, saving 60% of floor space, and is completely automatic. No operator is required. It fits perfectly into an automated production line.

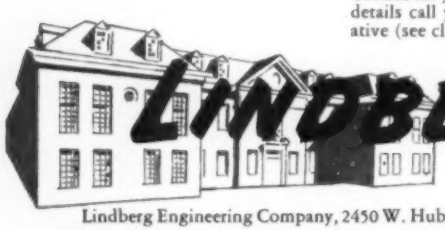
Our High Frequency Division provides units for hardening, brazing, soldering, annealing and many other processes and designs a variety of fixtures for application to "H-F" units. Lindberg also supplies a complete line of motor generators for all induction heating and melting applications. This equipment is available for M-G set frequencies of 1 KC., 3 KC. and 10 KC. and in power outputs from 30 KW. to 1250 KW.



Lindberg also specializes in field installation. We call this part of our business Lindberg Industrial. Whether your requirements call for the installation of a big one like the aluminum reverberatory furnace shown below or a complete heat treating department of smaller units, Lindberg will handle the job all the way. We specialize in "turn-key" installations, covering everything from design and engineering to the finished job. This includes all the construction needed to fit the equipment into your production processes.



Thanks for your attention to this brief story. For full details call your nearest Lindberg Field Representative (see classified phone book) or write us direct.



heat for industry

Lindberg Engineering Company, 2450 W. Hubbard St., Lindberg Industrial Corporation, 2321 W. Hubbard St., Chicago • Los Angeles plant, 11937 S. Regentview at Downey, California • EFCO-Lindberg, Ltd., Montreal, Canada • Lindberg Italiana, Milan, Italy The Electric Furnace Company, Ltd., Weybridge, Surrey, England • Etablissements Jean Aubé, Paris, France • Lindberg Industrie Ofenbau, Gross Auheim, Germany • Toyo Menka, Tokyo • Lindberg Engineering Company (Australia) Pty. Ltd., Melbourne

Printed in U. S. A.

INVESTMENT CASTINGS THIS BIG...

are just part of the Kolcast story

This bulkhead for a missile is 30 inches in diameter, weighs 250 pounds. It was cast in high-strength, high-temperature alloy steel by Kolcast as an investment casting. It has *not* been machined! As-cast surfaces, contours and dimensions are so accurate that only a bare minimum of surface metal will have to be removed to prepare it for assembly.

Parts produced by Kolcast can be as small as a cigar, as large as a washing machine . . . can weigh ounces or as much as 500 pounds. They are made with permeable inorganic ceramic molds.

Kolcast also produces vacuum-melted, vacuum-cast parts from such super-alloys as Waspalloy, MT-252, GMR-235, Rene-41, M-308 and similar melts. The country's largest induction vacuum melting furnace, and Kolcast's exclusive process, keep super-alloy melts and castings free of oxygen and other strength-sapping gases.

A Kolcast technical man can give you case histories on Kolcast parts.

Visit us at Booth 1326 in Exhibition Hall,
during the National Metal Exposition in Chicago
. . . or write for Booklet MP-10.

KOLCAST INDUSTRIES *Inc.*

16601 EUCLID AVENUE • CLEVELAND 12, OHIO

Let's LAUGH a minute

Of course everyone knows that heat treating today has become one of the most serious technical and vital functions of the current metalworking activity. But a smile and laughter are still also important and the cartoons shown here are for that purpose.

We hope they make you grin and when it's heat treating services you require or skilled, technical advice about part design or heat treatability, check with

METAL TREATING INSTITUTE
271 NORTH AVENUE
NEW ROCHELLE, NEW YORK

or any member listed below.

Sound Familiar?
SMEARCASE, THE PRODUCTION MAN, SCHEDULES A JOB THROUGH HIS PLANT WITH TIME TO WASTE!
LET'S SEE... PLENTY OF TIME FOR A GOOD JOB ON OPERATION 1...NUMBER 2 SHOULD BE ABLE TO OOZE ALONG NICELY... AMPLE TIME FOR OPERATION NUMBER 3...THEN OUT IT GOES FOR HEAT TREATMENT
PRODUCTION SCHEDULE
OPER. #1
OPER. #2
OPER. #3
BUT... WHEN THE HEAT TREATER GETS IT...IT'S IN AN AWFULLY GREAT HASTE!
SMEARCASE! HOW'S THAT JOB COMING? TIME'S RUNNING OUT!!
FINE, BOSS! I GOT IT TO THE HEAT TREATER, 10 MINUTES AGO, I'M CHECKING WITH THEM NOW!
HELLO! ABC HEAT TREATING?
WHAT? NOT THROUGH WITH OUR JOB? DO YOU REALIZE WE HAVE A TIGHT SCHEDULE? TRYING TO MAKE ME LOOK BAD, HUH?.. BLAH, BLAH, BLAH...

Sound Familiar?
CARELESS MILFORD IS NOT PARTICULAR ABOUT THE PARTS HE SENDS IN FOR HEAT TREATING
BOY!...TAKE A LOOK AT THIS CASTING!
...OFF SIZE, NICKED, CRACKED AND WHAT HAVE YOU. HOW DID IT EVER GET OUT OF THEIR PLANT,...OR DON'T THEY CARE?
Instrule Heat Treating Co.
BUT... WHEN HE GETS THEM BACK... WHAM! LOOK WHO GETS THE BLAME!!!
CALL YOURSELVES METAL TREATERS? HAH! YOU SURE GAVE OUR CASTINGS THE 'TREATMENT'! - THEY GO OUT OF HERE 100% PERFECT,... AND WHAT HAPPENS? DO YOU DROP 'EM OFF THE ROOF OR JUST RUN A TANK OVER THEM?.. IF YOU HAVE NO CONSIDERATION FOR A CUSTOMER'S PRODUCT I'LL JUST HAVE TO...

American Metal Treatment Co.
Elizabeth, New Jersey
Anderson Steel Treating Co.
Detroit, Michigan
Benedict-Miller, Inc.
Lyndhurst, New Jersey
Bennett Heat Treating Co., Inc.
Newark 3, New Jersey
Commercial Metal Treating, Inc.
Bridgeport, Conn.
Cook Heat Treating Co. of Texas
Houston 11, Texas
The Dayton Forging & Heat Treating Co.
Dayton 3, Ohio
Dominy Heat Treating Corp.
Dallas, Texas
Drever Company
Philadelphia 33, Pennsylvania
Greenman Steel Treating Company
Worcester 5, Massachusetts
Fred Heinzelman & Sons
New York 12, New York
Alfred Heller Heat Treating Co.
New York 38, New York

MTI MASTER TREATMENT METAL TREATING INSTITUTE

Hollywood Heat Treating Co.
Los Angeles 38, California
L-R Heat Treating Company
Newark, New Jersey
The Lakeside Steel Improvement Co.
Cleveland 14, Ohio
Metallurgical, Inc.
Minneapolis 14, Minnesota
Metallurgical, Inc.
Kansas City 8, Missouri

New England Metallurgical Corp.
South Boston 27, Massachusetts
Paulo Products Company
St. Louis 10, Missouri

Pittsburgh Commercial Heat Treating Co.
Pittsburgh 1, Pennsylvania
Pittsburgh Metal Processing Co., Inc.
Pittsburgh 15, Pennsylvania
The Queen City Steel Treating Co.
Cincinnati 25, Ohio
J. W. Rex Company
Lansdale, Pennsylvania
Stanley P. Rockwell Company
Hartford 12, Connecticut
Scott & Son, Inc.
Rock Island, Illinois
Standard Steel Treating Co.
Detroit 10, Michigan
Syracuse Heat Treating Corp.
Syracuse, New York
Winton Heat Treating Company
Cleveland 16, Ohio

CANADA

B. & W. Heat Treating Ltd.
Kitchener, Ontario
Ipsenlab of Canada Ltd.
Toronto, Ontario

per strike, Alkontrol improves the deposition of copper casting patterns, and plating in low current density areas. It is added directly to cleaning baths at the rate of ¼ oz. per gal.

For further information circle No. 991 on literature request card, page 48-B.

Automatic Heat Treating

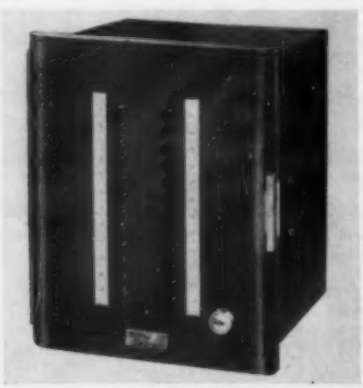
Ipsen Industries, Inc. has announced new loaders and unloaders for handling work in and out of automatic heat treating units. They require a little more floor area than the

physical size of the work trays they handle. Both units are available for stationary mounting or can be equipped with free running or motor driven wheels-on-track for transverse servicing of a number of furnaces, washers, or related accessories.

For further information circle No. 992 on literature request card, page 48-B.

Temperature Measuring

A new line of push-button selector switches for temperature measuring circuits has been announced by Thermo Electric Co. These switches permit checking of remote thermocouples or resistance bulbs from one



location. In addition, they also permit the averaging of temperatures from a number of sensing elements. They can be used with all types of pyrometers and resistance thermometers. All switches have cross-bar palladium contacts with contact springs of tempered nickel-silver.

For further information circle No. 993 on literature request card, page 48-B.

Drawer Oven

Blue M Electric Co. has announced a heavy-duty drawer oven with automatic control system of wattage proportionment to temperature and work load. Standard model has 5 individual sliding, nontilting, perforated drawers, 18½ by 20 by 5 in. in size. It operates in the temperature range of 100 to 400° F.

For further information circle No. 994 on literature request card, page 48-B.

Rust Proofing

Heatbath has announced a new rust proofer for ferrous metals. Rustgard is mixed 1 to 20 parts with water and applied by immersion or spray at temperatures up to 212° F. It is used on ferrous metals to prevent rust after machining, stamping, drawing and forging; during assembly, storage and shipping; and as a final protective finish over conversion coatings such as black oxide and phosphates.

For further information circle No. 995 on literature request card, page 48-B.

Tube Cutting

Pipe and tubing ranging in size from ⅝ to 1¼ in. o.d. in light gage to 16-gage wall thickness, can be cut on a new air-operated rotary cutoff machine, announced by Continental Machine Co. The operator feeds the pipe or tube to a pre-set stop, touches the air valve foot switch and the rotary blade descends at the desired cutting speed, cutting the material.

For further information circle No. 996 on literature request card, page 48-B.

Electrode Holders

Air Reduction Co. has announced new light-weight air-cooled and water-cooled manual holders, a heavy-duty water-cooled manual holder, and three new water-cooled machine holders for automatic and semi-automatic Heliwelding. Manual holders are 7½ in. long and weigh 4 oz. They have interchangeable lava nozzles, collets and caps. Machine holders are continuous duty and rated at 500 amp. d.c.

For further information circle No. 997 on literature request card, page 48-B.

Ultrasonic Transducer

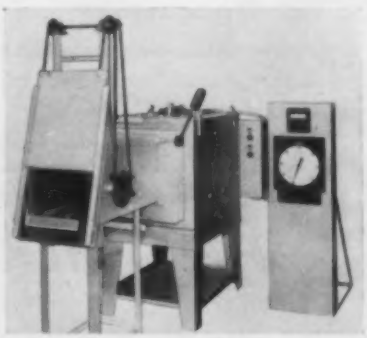
A new ultrasonic transducer for ultrasonic cleaning, degreasing, and processing has been announced by Vibro-Ceramics Div., Gulton Industries, Inc. Using Glennite piezoelectric ceramics, the ultrasonic transducer is designed for modular assembly to cover large areas with a nonfocusing and uniform sound field. It is hermetically

sealed in stainless steel housing and is completely immersible in organic solvents, aqueous solutions of normal detergents, mild alkalis or acids.

For further information circle No. 998 on literature request card, page 48-B.

Atmosphere Furnace

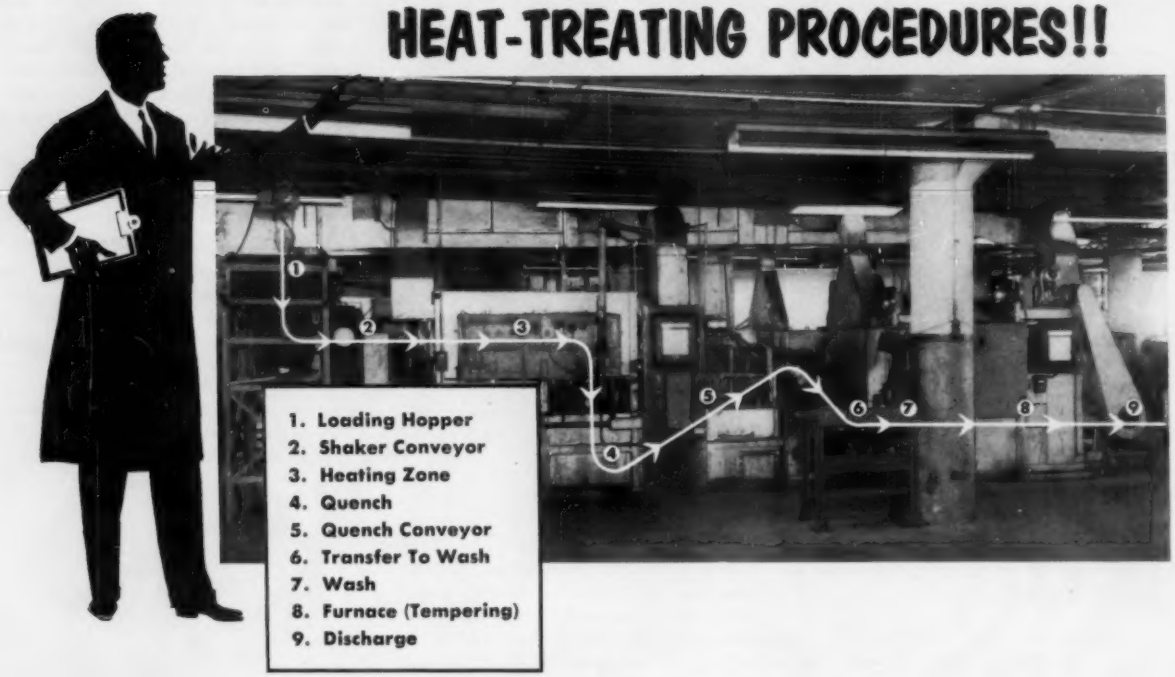
L & L Mfg. Co. has announced a new combination of alloy muffle heat-treating furnace and atmosphere generator. An elevator carries the metal



parts to be heat treated to a vestibule where they are pushed into the firing chamber. The atmosphere generator uses an alcohol-water mixture as the material from which the atmosphere is generated.

For further information circle No. 999 on literature request card, page 48-B.

Now you can AUTOMATE your HEAT-TREATING PROCEDURES!!



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Parts are then carried from the quench by *conveyor* (5) which discharges to *chute* (6) They then proceed through *wash* (7) and enter *tempering furnace* (8) and on to subsequent finishing processes.

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- ☐ Tool Steel Hardening
- ☐ Carbo-Nitriding
- ☐ Tempering
- ☐ Vacuum Heat Treating
- ☐ Bright Heat Treating
- ☐ Stainless Steel Heat Treating
- ☐ Sintering
- ☐ Copper Brazing and Soldering
- ☐ Lead Pot Hardening and Tempering
- ☐ Atmosphere Equipment
- ☐ Other

Name ..... Title .....

Company .....

Street .....

City ..... State .....

APPLICATION and EQUIPMENT new literature

1001. Abrasion Tester
Bulletin 5409 on new model standard abrasion testing set describes machine and its operation. *Taber Instrument Corp.*

1002. Abrasives
New catalog on various types of shot and grit abrasives. SAE specifications and types of cleaning and peening methods. *Cleveland Metal Abrasive*

1003. Abrasive Cleaning
Folder on Malleabrasive for airless blast cleaning equipment gives advantages, grades, equipment it may be used with and parts that may be cleaned. *Globe Steel Abrasive*

1004. Air Washers
Bulletin No. 256 on acid-proof air washers for ventilation systems. Construction and accessories. *Automotive Rubber Co.*

1005. Alloy Castings
8-page bulletin on alloy castings for heat treating. *Ohio Steel Foundry*

1006. Alloy Castings
22-page bulletin 2041 on heat and corrosion resistant castings. *Blaw-Knox*

1007. Alloy Chart
Comparison of AISI, SAE, ACI, AMS, WAD and PWA chromium and chromium-nickel stainless specifications. *Cannon-Muskegon*

1008. Alloy Steel
Data book on the selection of the proper alloy steel grades for each manufacturer's needs. *Wheelock, Lovejoy*

1009. Alloy Steel
14-page bulletin on two chromium-nickel alloy steels. Properties, working instructions, heat treatment, recommended uses. *Carpenter Steel*

1010. Alloy Steel
16-page book on type 9115 low-alloy high-strength steel. Properties, fabrication, welding. *Great Lakes Steel*

1011. Alloy Steel
207-page book gives more than 50 complete case histories of alloy steel usage. *Climax Molybdenum*

1012. Aluminum
16-page bulletin lists sizes, weights, lengths of aluminum in rod, bar, plate, sheet. Guide to selection, finishes, mechanical properties. *Ryerson*

1013. Aluminum Alloy
Bulletin 103 on high strength aluminum alloy which ages at room temperature. *Federated Metals Div.*

1014. Aluminum Alloys
File on high-strength aluminum alloys gives advantages, applications, properties. *Frontier Bronze Corp.*

1015. Aluminum Bonding
Brochure on Alumi-coat process of bonding aluminum and its alloys to ferrous metals. *Arthur Tickle Eng'g. Works*

1016. Aluminum Bronze Alloys
20-page booklet on chemistry, physical properties and uses of aluminum bronze alloys in rolled, extruded and cast forms. *Ampco*

1017. Aluminum Extrusions
Folder lists alloys used, finishes, trade phraseology. *General Extrusions, Inc.*

1018. Aluminum Extrusions
28-page book on extruded aluminum products. Design, tolerances, applications. *Revere*

1019. Aluminum Strip
20-page booklet on how it is made, sizes and weights of coils. Technical data on aluminum alloys used. *Scovill*

1020. Ammonia
New 69-page data book on anhydrous ammonia and ammonia liquor. Chemical and physical properties, specifications, analytical procedures, bibliography. *Nitrogen Div.*

1021. Analysis of Nickel Alloys
52-page Technical Bulletin T-36, "Methods for Chemical Analysis of Nickel and High-Nickel Alloy." *International Nickel*

1022. Annealing
4-page reprint No. 62 on salt bath annealing of cold finished sections. *Ajax Electric*

1023. Atmosphere Control
8-page bulletin on furnaces, atmosphere equipment, controls for bright annealing, hardening and tempering, batch annealing, age hardening and carburizing. *Surface Combustion Corp.*

1024. Atmosphere Furnace
12-page bulletin 1054 on electric furnaces with atmosphere control for hardening high speed steel. *Sentry*

1025. Atmospheres
Bulletin 1-10 supplies technical information on inert gas generators and data on costs. *C. M. Kemp Mfg.*

1026. Atmospheres
12-page Bulletin GEA-5907 on three gases. Case histories. Selection guide for different heating applications. *General Electric*

1027. Automatic Controls
56-page catalog 857 on automatic controls for heating and industrial applications—pressure, temperature, liquid level, etc. *Mercoid Corp.*

1028. Bimetal Applications
44-page booklet. "Successful Applications of Thermostatic Bimetal," contains uses, formulas, calculations. *W. M. Chace*

1029. Blast Cleaning
24-page catalog 1210 on equipment and accessories for blast cleaning and dust control. *Pangborn*

1030. Boron Stainless
8-page booklet on composition, structure, corrosion resistance, welding and mechanical properties of 1% boron stainless steel. *Superior Steel Corp.*

1031. Brazing
8-page bulletin S-1050 on production brazing and soldering with automatic machines. Construction of custom models. *Selas*

1032. Brazing Carbide
Bulletin 542 on brazing hard carbide with Silvaloy plymetal. Joint requirements, brazing procedure, thermal stress in brazing carbide tips. *American Platinum Works*

1033. Bronze Bearings
12-page bulletin on Promet bronze bushings, bearings, bar stock and babbitt metal. Technical data. Case histories. *American Crucible Products Co.*

1000. Refractories
A new 24-page cement mortar manual contains information on mortar preparation, placing procedure and general instructions for gun-applied linings in oil refineries, power

plants, metal and similar industries. An appendix adds data on selected aggregates, thermal conductivities and strength curves of concretes. The manual concludes with a bibliography of 68 recent articles on refractory concrete. *Universal Atlas Cement Co.*

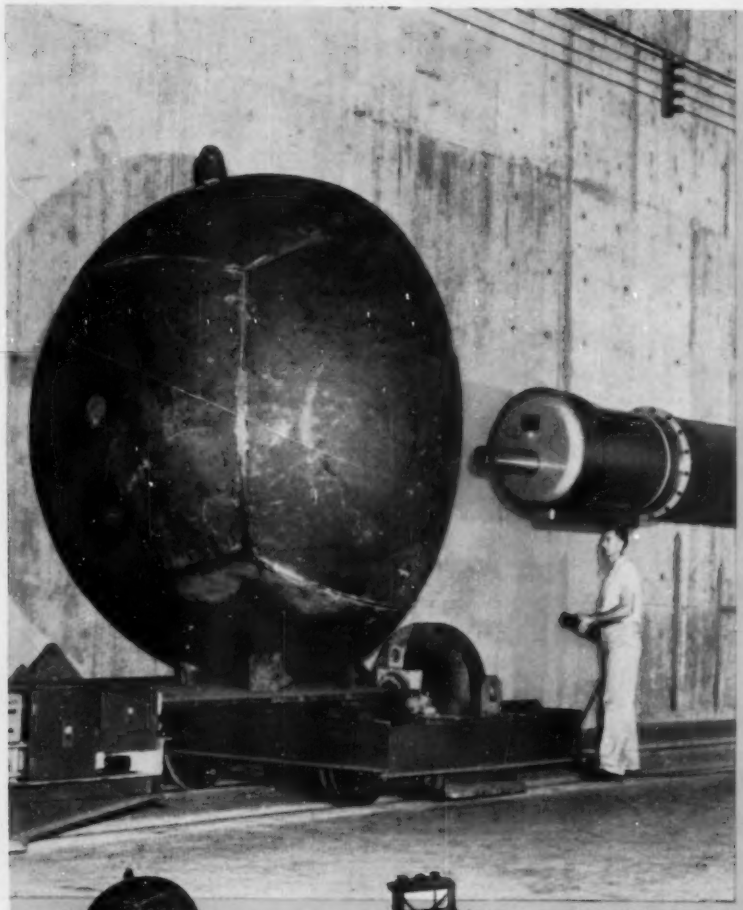
1034. Burners
New Buzzer catalog on industrial gas burners and gas furnaces for heat treating carbon and alloy steels. Pot furnaces and melting furnaces. *Charles A. Hones*

1035. Calculator
Data on calculator which adds, subtracts, multiplies, divides. *Utility Supply*

1036. Calibration
12-page brochure on proving rings in weighing and force measuring systems. Their uses, construction and operation. *Morehouse Machine*

1037. Carbides
15 data sheets on Carmet carbide grades. Typical applications, analysis, physical characteristics and grain structure. *Allegheny Ludlum Steel Corp.*

1038. Carbon Control
Bulletin C-22 and reprint on Carbontronik for automatic control of carbon potential of atmospheres. *Ipsen*



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1039. Carbon Control
12-page catalog TD4-620 (2) on Microcarb atmosphere control for carbon potential in Homocarb furnaces. *Leeds & Northrup*

1040. Carbon Dioxide Welding
12-page reprint on carbon-dioxide shielded consumable electrode arc welding. Methods of supplying and flow characteristics of carbon dioxide. Properties of weld metal. *Air Reduction*

1041. Castings
Bulletin 3150-G on castings for heat, corrosion, abrasion resistance. *Duraloy*

1042. Castings
Literature on shell or sand castings of ArmaSteel, malleable iron or gray iron. *Central Foundry Div.*

1043. Centrifugal Castings
12-page indexed catalog on custom-made centrifugal castings of 70 different alloys. Analysis and properties of heat, corrosion and abrasion resistant alloys, carbon and low alloy steels, nonferrous metals. *Sandusky Foundry and Machine*

1044. Chromate Finishing
File on chromate conversion coatings for prevention of corrosion and paint-base treatment of nonferrous metals. *Allied Research Products*

1045. Cleaning
20-page booklet on machinery for spray washing and pickling, phosphatizing, drying, vapor degreasing, heat treating and other metal parts processing. *Metalwash Machinery Corp.*

1046. Cleaning
48-page pocketbook on how to clean aluminum and magnesium. Steps involved, methods, equipment. *Oakite*

1047. Cleaning
Folder on steel shot for cleaning aluminum castings, gray iron castings, steel forgings and for shot peening. *Steel Shot Producers, Inc.*

1048. Cleaning Aluminum
12-page bulletin on cleaning process for preparing aluminum and magnesium for welding. *Northwest Chemical*

1049. Cold Cleaners
Bulletins 402 and 403 on cleaners for still tanks and 439 and 440 for power washers. *E. F. Houghton & Co.*

1050. Compressors
12-page data book 107-D gives engineering information on characteristics of turbo-compressors. 18 types of application described. *Spencer Turbine*

1051. Construction Kit
Folder and 60-page booklet on construction kit of selected standard elements to be used in solving engineering problems and instruction. *C. R. Carlson Co.*

1052. Contour Machines
16-page bulletin on equipment for contour sawing, filing, polishing operations. *DoAll Co.*

1053. Controlled Atmospheres
Bulletin on Dewpointer for reading of atmosphere in field and laboratory. Readily portable, operating on a.c. or enclosed battery. *Illinois Testing Labs.*

1054. Controlled Atmospheres
Bulletin 753 on generator for atmospheres for hardening, brazing, sintering and annealing carbon steels. *Hevi Duty*

1055. Controlled Atmospheres
Illustrated literature describes controlled atmosphere installations. *Gas Atmospheres, Inc.*

1056. Controllers
56-page bulletin on new series 500W pneumatic controller. Control principles and control modes available. *Bristol Co.*

1057. Conveyors
Bulletin MF-200 on conveyor standardization describes prefabricated sections for making customized conveyors. *May-Fran Engineering*

1058. Copper Alloys
40-page technical data book on eleven copper alloys. Properties, cleaning, annealing. *Seymour*

1059. Corrosion Protection
New 16-page bulletin on corrosion proof construction materials includes sections on corrosion proof cements, tank linings, protective coatings and others. *Atlas Mineral Products*

1060. Creep Testers
Data file lists 8 models, gives salient features and illustrates them and uses. *Arcweld Mfg.*

1061. Cutting Stainless
8-page bulletin on shearing, blanking, perforating, friction sawing and flame cutting of stainless. *Crucible Steel*

1062. Cutting Tools
New 12-page catalog D-56 on aluminum oxide cutting metals, tool tips, throw-away inserts, cylinders and other machine turning and cutting tools. *Metal Carbides*

1063. Degreasers
Folder on vapor and solvent degreasers describes equipment and advantages. *Randall Mfg.*

1064. Degreasing
34-page booklet on vapor degreasing. Design, installation, operation and maintenance of equipment. *Circo Equipment*

1065. Descaling Stainless Steel
Bulletin 25 on descaling stainless steel and other metals in molten salt. *Hooker Electrochemical*

1066. Die Sections
12-page bulletin on composite die sections. Steels used, sizes, heat treating data, engineering data, examples. *Composite Forgings, Inc.*

1067. Die Sets
Catalog shows complete line of ball bearing die sets. *Lempco Products*

1068. Disintegrators
Catalog B-1 on disintegrator which will remove embedded broken tools. Specifications. *Jiffy Disintegrator*

1069. Dryer
New bulletin 130 describes Aero after cooler for removing moisture from compressed air and gas. Application of equipment. *Niagara Blower Co.*

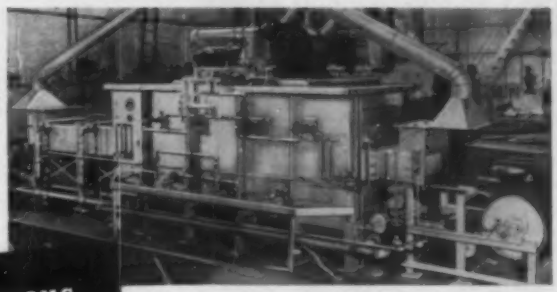
1070. Ductility Testing
New bulletin on simple method of determining ductility of materials before drawing. *Steel City Testing Machines*

1071. Electric Furnaces
Bulletin on electric heat treating furnaces gives summary of progress in furnace developments. *Holcroft*

1072. Electric Furnaces
Data sheet describes and gives specifications of standard non-metallic resistor furnaces. *Harrop Electric Furnace Div.*

1073. Electric Furnaces
Folder on electric furnaces with zone control, temperature indication, automatic control. *L & L Mfg. Co.*

1074. Electric Furnaces
8-page Bulletin 570 on heat treating, melting, metallurgical tube, research and sintering furnaces. Custom designs for special requirements. *Pereny*



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12-page bulletin on box-type electric furnaces for toolroom applications. Performance data for each type. *Westinghouse Electric Corp.*

1076. Electric Furnaces
16-page Bulletin No. 559 on melting, investment casting and other furnaces. Capacities and special features. *Detroit Electric Furnace*

1077. Electrocoated Wire
8-page bulletin on new wire materials—Nickelply and Brassply, electrocoated steel wire. How it may be formed, bent and twisted. *National Standard*

1078. Electrode Shipments
Data on damage-free gondola cars used to ship carbon and graphite electrodes. *National Carbon*

1079. Electrolytic Iron
New 4-page folder on uses and properties of 99.9% pure iron. *Van der Horst*

1080. Electron Microscope
12-page bulletin gives construction and operation. Electron optical system, accessories. *Philips Electronics*

1081. Electron Microscopy
4-page bulletin on specimen preparation for electron microscopy. *RCA*

1082. Electron Tubes
Folder on tubes for industry, research and other applications. Separate data sheets give description, operating conditions, constant current characteristics. *Machlett Laboratories*

1083. Electropolisher
Theory and practice of electrolytic polishing of metallurgical samples. Describes electropolisher. Metal Digest, Vol. 1, no. 5. *Buehler, Ltd.*

1084. Endothermic Atmospheres
16-page reprint on endothermic atmospheres for heat treatment of steel. Effect of temperature on atmosphere. Calculating analysis. *Electric Furnace Co.*

1085. Extensometer
8-page bulletin on extensometers for sheet metal and wire, compressometers, deflectometers and other accessories. *Baldwin-Lima-Hamilton*

1086. Extrusion
Folder describes the hot extrusion process and gives its history. *Jones & Laughlin*

1087. Extrusions
Bulletin on extruded seamless alloy and stainless steel tubing. Properties, shapes. *Metals Processing Div., Curtiss-Wright*

1088. Extrusions
New 20-page booklet on extruded rod and bar stock in beryllium copper, beryllium aluminum and beryllium nickel alloys, beryllium metal and oxide. *Beryllium Corp.*

1089. Fabrication
Booklet on welded steel heavy fabrication pictures and describes how various products are made. *R. C. Mahon*

1090. Ferro-Alloys
32-page book tells how ferro-alloys are made and how they are used. *Electro Metallurgical Co.*

1091. Finishing
New 52-page barrel finishing handbook. Modern processes described. *Almco Div.*

1092. Finishing
Six bulletins describing finishing compounds for stainless steel, aluminum, other metals. *Apothecaries Hall*

1093. Finishing Machines
Data sheet on centerless bar turning machines, bar straightening and polishing machines, swaging machines, roller flattening and cutting machines. *Sutton Engineering*

1094. Flame Hardening
20-page booklet on precision flame hardening machine with electronic control. Details of operation and applications. *Cincinnati Milling Machine*

1095. Flaw Location
4-page folder on dye penetrant method of flaw location. *Turco*

1096. Flow Meters
Bulletin 203 on flow meter for gas used in heat treating. *Waukee Eng'g*

1097. Forging Rolls
12-page Bulletin 91-B on wide adjustment forging rolls illustrates equipment, lists accessory equipment and gives principal dimensions. *Ajax Mfg.*

1098. Forgings
New folder on facilities for production of flat-die forged products. Electronic equipment used. *Smith-Armstrong*

1099. Forgings
Bulletin on forge steelmaking, open die forging, machining, heat treating and finishing. *National Forge*

1100. Forgings
8-page brochure on facilities and quality control for making steel and forgings. *Pencoyd Steel and Forge Corp.*

1101. Forgings
12-page booklet on how forged weldless rings and flanges are made. Case histories. *Standard Steel Works Div., Baldwin-Lima-Hamilton*

1102. Forgings
94-page book on die blocks and heavy-duty forgings. 20 pages of tables. *A. Finkl & Sons*

1103. Forming
86-page book on equipment and process of cold roll-forming. Wide sheets, narrow trim, tubular shapes, curving, coiling, tooling needed. *Yoder*

1104. Free-Machining Steel
8-page bulletin gives machinability, heat treatment, fatigue resistance, and tensile properties for 0.45% carbon steel. *Horace T. Potts Co.*

1105. Furnace
Article on car-type furnace for heat treating castings at General Railway Signal Co. in Metal Minutes, June 1957. *Sunbeam*

1106. Furnace Belts
42-page booklet on alloy steel belts for continuous high-temperature furnaces. Belt selection guide. *Wickwire Spencer Steel Div.*

1107. Furnace Belts
44-page catalog describes metal belts for quenching, tempering, carburizing and other applications. *Ashworth Bros.*

1108. Furnace Fixtures
16-page catalog on baskets, trays, fixtures and carburizing boxes for heat treating. 66 designs. *Stanwood*

1109. Furnaces
Bulletin on electric heat treating furnaces describes five series and accessories. *Lucifer Furnaces*

1110. Furnaces
Bulletin 424R on gas, oil, and electric revolving retort furnaces for annealing, hardening, drawing. *W. S. Rockwell Co.*

1111. Furnaces
Data on line of melting, heating and heat treating furnaces for ferrous and nonferrous metals. *Loftus Engineering*

1112. Furnaces
Folder on recirculating furnaces illustrates and describes 9 models and endothermic gas generator. *Standard Fuel Engineering Co.*

1113. Furnaces
Folder describes complete set up for heat treatment of small tools, including draw furnace, quench tank and high temperature furnace. *Waltz Furnace*

1114. Furnaces
32-page catalog of industrial equipment includes furnaces and furnace accessories, special valves, mechanical equipment, materials handling. *Salem-Brosius*

1115. Fused Quartz
New brochure on fused quartz and silica for use in furnaces and laboratory equipment. Properties and how they are formed into usable products. *Amersil Co.*

1116. Galvanometers
12-page bulletin No. 320 on three different types of galvanometer. Factors affecting selection. *Rubicon*

1117. Gold Plating
Article on analysis of gold and gold alloy plating solutions gives all currently available procedures. *Technic*

1118. Graphite
4-page catalog section S-5050 on impervious graphite and resin-base cements for corrosive service. 2-page table gives recommendations for commercial applications. *National Carbon*

1119. Graphite
4-page folder on graphite crucibles, funnels, and special preformed electrodes. High-purity powder. *United Carbon Products Co.*

1120. Graphite Electrodes
Vest-pocket notebook containing 90 pages of information on electric furnace electrodes and other carbon products. *Great Lakes Carbon Corp.*

1121. Hard Facing
New 4-page bulletin on corrosion resistant hard facing overlays. Processes for applying surfaces; properties of cobalt-chromium-tungsten facings. *Cleveland Hard Facing, Inc.*

1122. Hard Surfacing
40-page hard facing manual tells what metals can be hard faced, how to select right hard facing material, lists step-by-step procedures and industrial applications. *Haynes Stellite*

1123. Hardenable Steels
16-page reprint tells how chemical composition affects ductility and notch toughness. Triple alloy steels compared with double or single alloy steels. *International Nickel*

1124. Hardness Conversion
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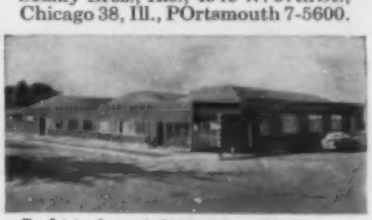

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(Continued on page 48-A)

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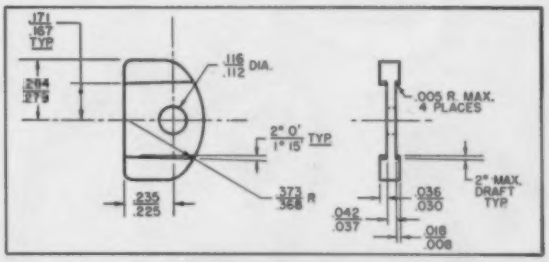

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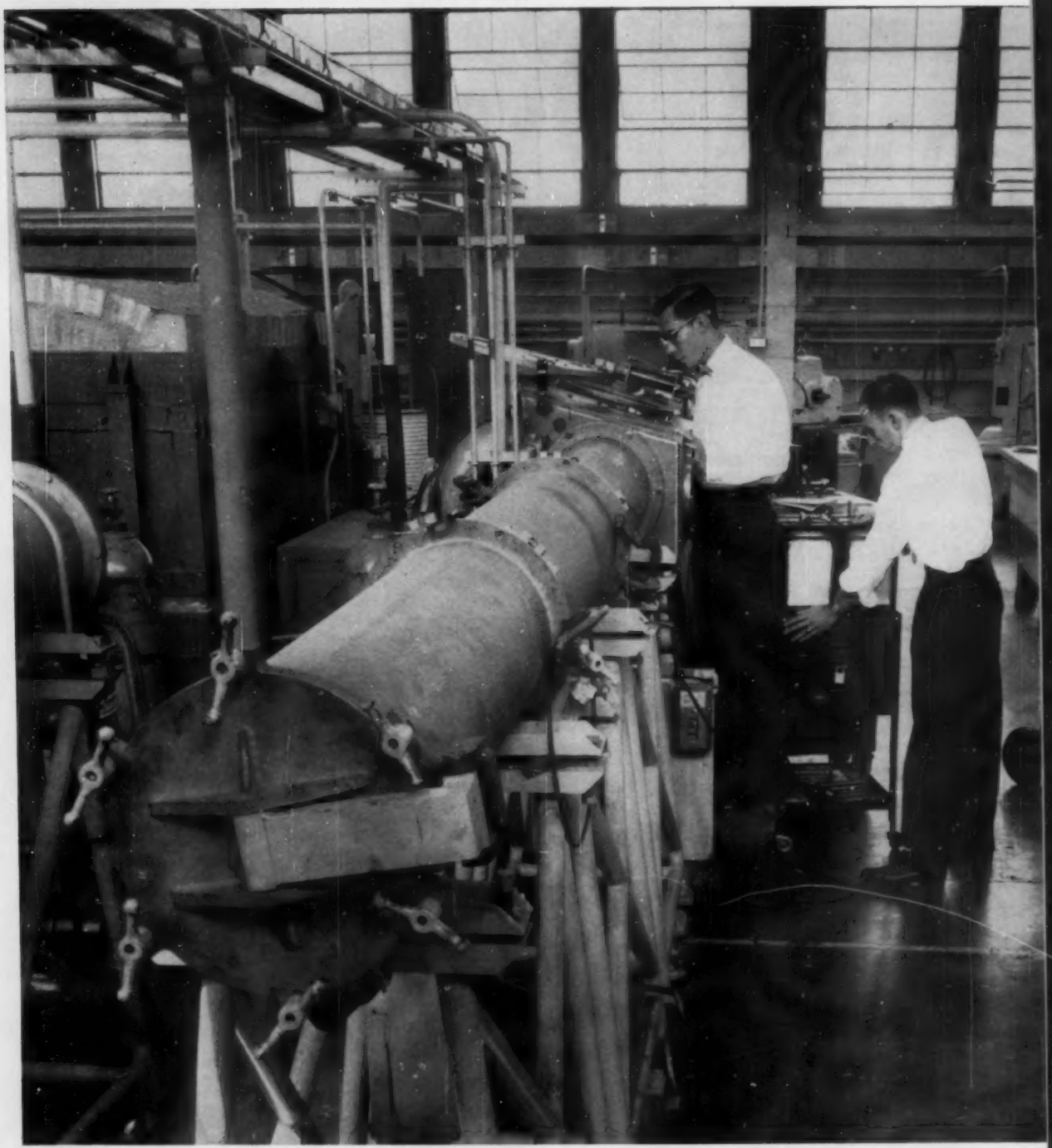

James G. Goodwin (Penn State '51), Senior Engineer in the Special Materials Section of Bettis Atomic Power Division, on left, examines a completed weld made on the central thimble tube. Mr. Goodwin directed the program to develop the proper process for fabricating Zircaloy-2 Pressure Vessel for irradiation studies. Richard M. Lieberman (Lafayette '52), Associate Engineer in the Loop Design and Operation Group, checks voltage and amperage records of the welding performance.

METALLURGICAL PROCESS DEVELOPMENT

Fabrication of Zircaloy-2 Pressure Vessel for Irradiation Studies

To test fuel elements being developed for a pressurized water reactor, engineers at Bettis Atomic Power Division have constructed an in-pile loop capable of sustaining fuel element temperatures and heat output conditions which approximate and even exceed actual reactor operating conditions. Stainless steel had been used for such loops. However, since increased neutron efficiency was desired, consideration was given to materials with lower neutron cross sections. A zirconium alloy (Zircaloy-2) was selected as an alternate material because, in addition to low thermal-neutron absorption, it has excellent corrosion resistance to high temperature water.

After Richard M. Lieberman, Associate Engineer in the Loop Design and Operation Group, designed the tube, James G. Goodwin, Senior Engineer in the Special Materials Section, directed a program to develop the proper process for fabricating the apparatus which was to be capable of withstanding 2500 psi internal pressure at 650°F. The vessel, constructed from a tubular extrusion (4.520 in. OD x 3.136 in. ID x 22 ft ¾ in. long) was one of the largest single items ever manufactured from Zircaloy-2 and involved problems in four major areas: extrusion, machining, welding, and corrosion resistance.

Several problems were anticipated in extruding the tube. First, the severe galling tendency of Zircaloy created lubrication problems particularly on the tube ID. The long extrusion billet and the relatively small ID of the tube introduced problems concerned with the strength of a long, thin mandrel under the severe tensile forces of extrusion. Because of the small amount of metal cleanup allowed for the ID due to mandrel diameter limitations, good concentricity of the extruded tube was mandatory.

In order to straighten the 22 ft tube for accurate and precise machining, cold deflections of up to 7 in. were required.

The problem of producing sound welds included the need for complete penetration at the weld joints and rotation of the massive unit at a uniform speed during filler metal additions. Since contamination with air during welding would have produced brittle and corrodible welds, the tube had to be welded in an inert atmosphere.

Closeup of closure for Zircaloy in-pile tube.

To insure corrosion resistance of the finished tube, a layer of disturbed metal formed on the Zircaloy during machining had to be removed by etching. The configuration of the tube created difficulties in maintaining dimensional tolerances during the process and in removing all traces of corrosive acid.

The completed tube was installed in March, 1957 and has been operating continually in a large test reactor. During this development project, close technical cooperation was maintained throughout by Bettis and the test reactor personnel on design, fabrication and evaluation of the tube.

This is only one example of the challenging work conducted here. We welcome inquiries from metallurgists interested in the excellent careers offered by the new and growing nuclear power industry. Please send your résumé to: Mr. M. J. Downey, Bettis Atomic Power Division, Westinghouse Electric Corporation, P.O. Box 1468, Department A208, Pittsburgh 30, Pennsylvania.

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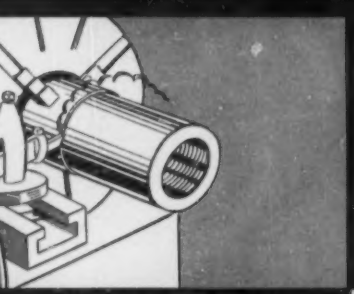
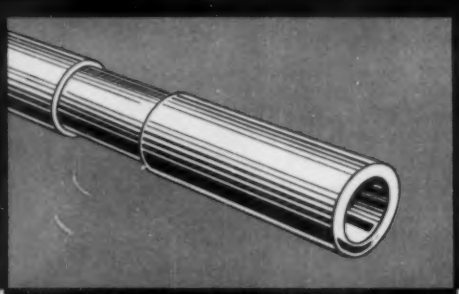
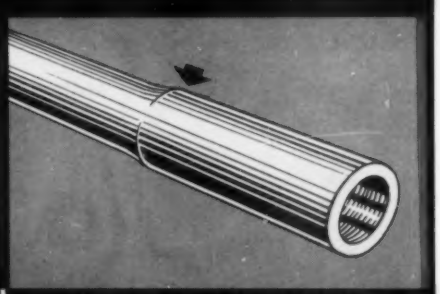


Worn drill collars are "peeled down" for perfect roundness, eliminating surface scars and imperfections.



Tubing sleeve is shrunk into perfect position.



Sleeves are securely welded. Thus drill collars go back into service actually as good as new.

MATCHING TUBES TO JOBS

Drill collars and tool joints can't last forever in oil well equipment service. Abrasive wear reduces the strength and the safe minimum O.D., and makes the bearing faces eccentric. When so worn, they are repaired by using sleeves—as shown above. One producer of such equipment brought a problem to B&W—"How could this 'sleeve' job be done with a minimum cost in equipment, operations, material and time?"

Because of the diversity of its types of tubular products and experience in matching tubes to jobs B&W was able to supply tubing in the proper type, size and grade and with appropriate tolerances and physical properties. This, in turn, reduced the number of fabricating operations and eliminated excessive machining and the need of some fabricating equipment. This manufacturer was able to "repair and place in as good as new condition" these rather expensive products—and at a substantial reduction in cost.

Friendly Mr. Tubes—your link to B&W—is the man to call when tubing can save the day in your own operation. His business is matching tubes to jobs—jobs like yours. The Babcock & Wilcox Company, Tubular Products Division, Beaver Falls, Pa.

TA-6106-M6

Seamless and welded tubular products, seamless welding fittings and forged steel flanges—in carbon, alloy and stainless steels.

(Continued from page 45)

slitters. Sheet and coil slitting methods summarized. *Stanat Mfg.*

1258. Smelting Equipment
48-page booklet 105 on equipment for smelting covers complete furnaces, electrodes and control equipment. *Lectromelt Furnace Div.*

1259. Sodium
28-page booklet on using sodium in dispersed form tells how dispersions are prepared and handled, and their advantages. *Ethyl Corp.*

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24-page brochure on prism and grating spectrographs and related accessories. Design, application and characteristics of each instrument. Performance. *Jarrell-Ash*

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Bulletin 339 on spot welder with predetermined electronic control. Circuits employed. *Sciaky Bros.*

1262. Spray Painting
16-page bulletin on electrostatic spray painting. How it is done. Case histories. *Ransburg Electro-Coating Corp.*

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1264. Stainless Castings
20-page booklet shows how they are made, property and size data, typical applications. *Crucible Steel*

1265. Stainless Steel
Booklet on 430 stainless. Properties, fabrication. *Sharon Steel*

1266. Stainless Steel
20-page catalog on corrosion resistance, applications and working characteristics of 20% chromium—29% nickel stainless steels, with and without columbium. *Carpenter Steel*

1267. Stainless Steel
28-page book on Type 430 nickel-free chromium stainless. Properties surface characteristics, fabrication, applications. *Washington Steel Corp.*

1268. Stainless Steel
Two booklets on 200 series of low nickel, austenitic stainless steels, give applications and properties compared with 300 series. *Republic Steel*

1269. Steel
14-page manual on sizes and types of electric furnace steel. List of products rolled from Byers melt. *A. M. Byers*

1270. Steel 52100
Stock list on 52100 tubing, bars and ring forgings. *Peterson Steels*

1271. Steel Castings
Bulletins on high and low carbon steel casting specifications. Allied specifications. *Unitcast Corp.*

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Bulletin on flame hardening, induction hardening, carbonitriding, nitriding, liquid carburizing, Chapmanizing. *Lakeside Steel Improvement*

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38-page catalog D-15 shows value of three-dimensional microscopes for industrial assembly lines and research laboratories. *Bausch & Lomb Optical*

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12-page booklet on industrial chilling equipment for shrinking, testing and treating of metals. *Cincinnati Sub-Zero*

1276. Sulphur Determination
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8-page bulletin on temperature control systems contains selection guide, terminology, types of control systems. *Wheelco*

1279. Temperature Indication
28-page bulletin on temperature indicating pigments. Ranges tested, directions for use, selection table. *Curtiss-Wright Corp., Research Div.*

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1282. Testing Equipment
80-page illustrated catalog lists over 130 testing and measuring tools for laboratory and production-line use. *General Electric*

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12-page catalog on ten testers including hardness, ductility, tensile, compression and transverse strength. *Detroit Testing Machine*

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16-page booklet on advantages and applications of textured metal. *Rigidized*

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32-page file book on pyrometer accessories. Selection of thermocouple and protective tube. *West Instrument Corp.*

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44-page catalog EN-S2 describes couples and assemblies for general application and for special plant and laboratory uses. *Leeds & Northrup*

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Folder on pocket-size gage. How to use it. *Ferro Corp.*

1289. Thickness Tester
Data sheets give ranges, principle of operation of nondestructive thickness tester. *Unit Process Assemblies*

1290. Thickness Testing
10-page bulletin 2253 on coating thickness gages. Standard and special purpose gages. *American Instrument*

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Interesting monthly report covers important current developments in the production, marketing and use of tin. *Malayan Tin Bureau*

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12-page booklet on C-120AV titanium alloy. Physical properties, elevated-temperature properties, creep, fatigue, welding, machining, heat treatment. *Rem-Cru*

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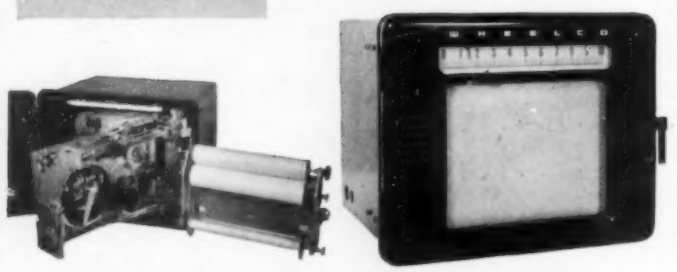

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air, oil and water hardening tool steels, alloy steels, machinery steels, stainless steels, welding rods. *Crucible Steel*

1297. Tool Steel

Fourth edition of the 204-page handbook. Types, properties and applications of tool steels. Selection, tool steel products, working tool and high speed steels. *Allegheny Ludlum Steel Corp.*

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1299. Tool Steel Color Guide

Color guide to estimate temperatures has heat colors on one side and temper colors on the other. *Bethlehem Steel*

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Memorandum No. 2 on Weldrawn tubing fabricated from cold-rolled strip, fusion welding the edges and cold drawing to size. *Superior Tube*

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1333. Zirconium Oxide

Product list gives chemical analysis, description and uses of four types of zirconium oxide. *Zirconium Corp.*

October, 1957

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963	992	1021	1050	1079	1108	1137	1166	1195	1224	1253	1282	1311
964	993	1022	1051	1080	1109	1138	1167	1196	1225	1254	1283	1312
965	994	1023	1052	1081	1110	1139	1168	1197	1226	1255	1284	1313
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969	998	1027	1056	1085	1114	1143	1172	1201	1230	1259	1288	1317
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971	1000	1029	1058	1087	1116	1145	1174	1203	1232	1261	1290	1319
972	1001	1030	1059	1088	1117	1146	1175	1204	1233	1262	1291	1320
973	1002	1031	1060	1089	1118	1147	1176	1205	1234	1263	1292	1321
974	1003	1032	1061	1090	1119	1148	1177	1206	1235	1264	1293	1322
975	1004	1033	1062	1091	1120	1149	1178	1207	1236	1265	1294	1323
976	1005	1034	1063	1092	1121	1150	1179	1208	1237	1266	1295	1324
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981	1010	1039	1068	1097	1126	1155	1184	1213	1242	1271	1300	1329
982	1011	1040	1069	1098	1127	1156	1185	1214	1243	1272	1301	1330
983	1012	1041	1070	1099	1128	1157	1186	1215	1244	1273	1302	1331
984	1013	1042	1071	1100	1129	1158	1187	1216	1245	1274	1303	1332
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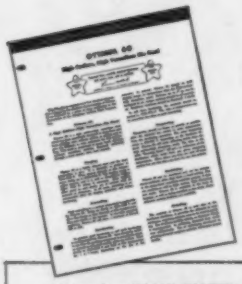

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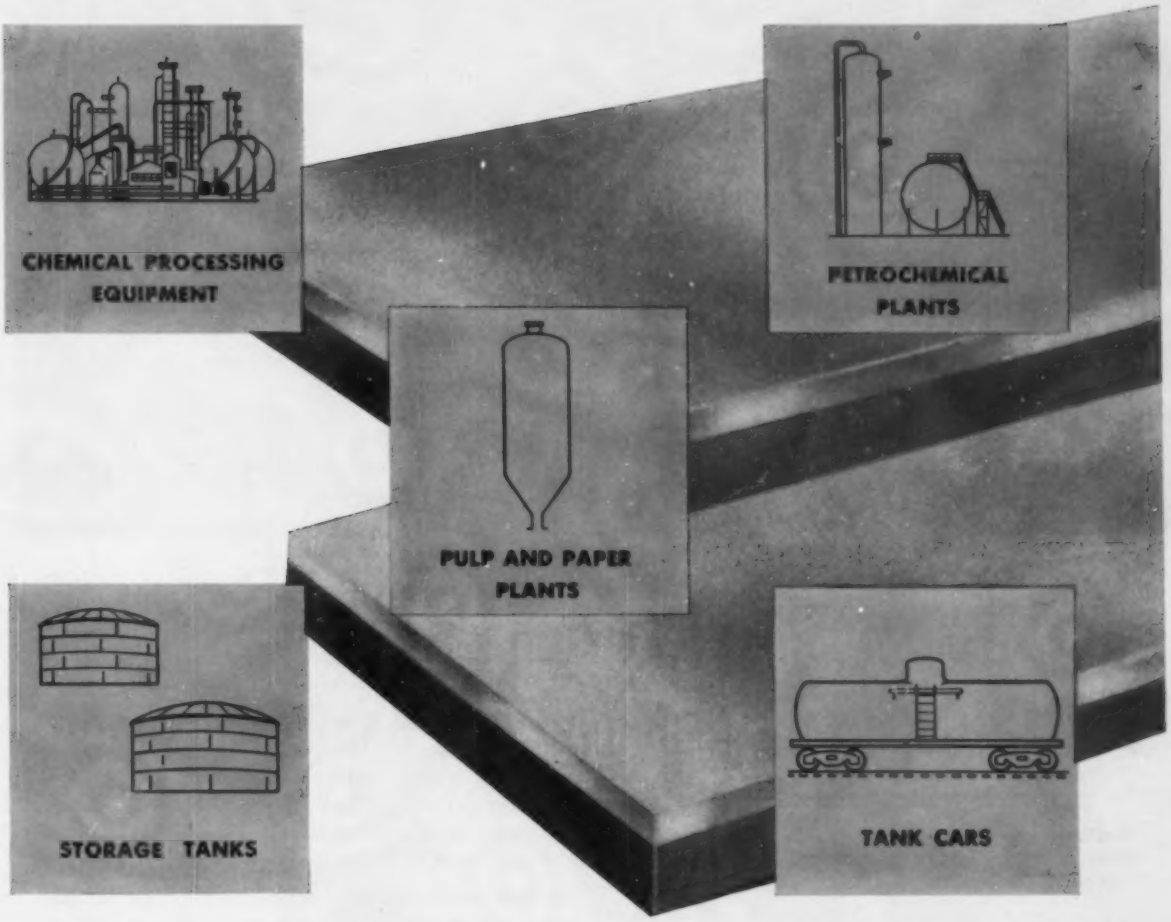

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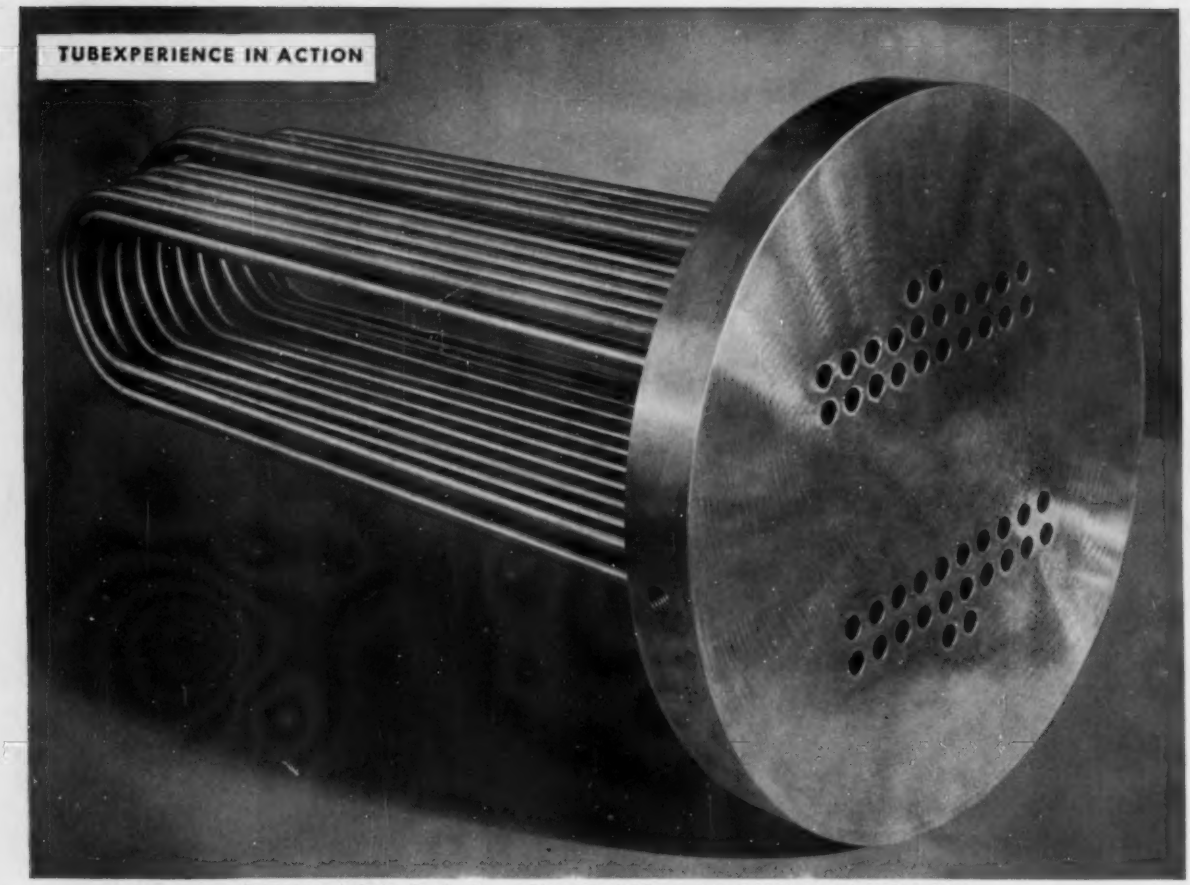

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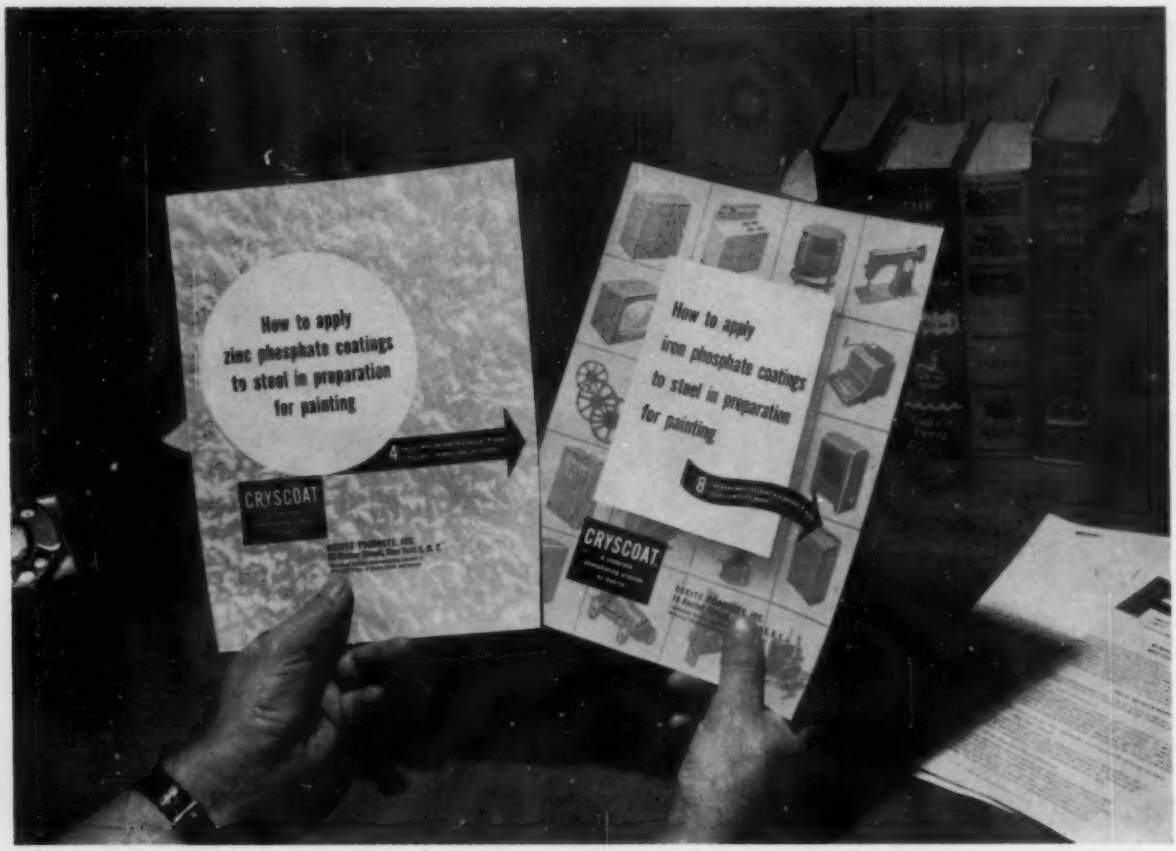

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If you paint-finish your steel products, you'll want these two fact-filled booklets on pre-paint-conditioning with Oakite *CrysCoat* phosphate coatings.

CrysCoating adds to your product's appearance and value by protecting against corrosion and providing a better base for paint adhesion.

With a *CrysCoat* process best suited for your particular product and equipment, you can turn out better-looking, longer-lasting finishes at lower cost.

Booklets show how phosphate coatings are applied; give special advantages of the *CrysCoat* process resulting in substantial savings over other processes.

USE THIS COUPON BELOW FOR YOUR COPIES OF THESE BOOKLETS. WRITE TODAY!

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Complete Phosphating Process

by OAKITE

SPECIALIZED INDUSTRIAL CLEANING
MATERIALS · METHODS · SERVICE
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Export Division Cable Address: Oakite

Technical Service Representatives in Principal Cities of U. S. and Canada

Oakite Products, Inc.,
26H Rector Street, New York 6, N.Y.

Gentlemen: Please send me information on the CrysCoat Phosphating Process for better paint finishes. Thanks.

NAME_____

COMPANY_____

TITLE_____

ADDRESS_____

CITY_____ STATE_____

Tool Steel Topics

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

Brake Die saves shop time in forming overlap for steel spout

The problem sounded simple enough — putting an overlap in a section of 20-gage stainless steel, which was then formed into a spout for use in meat-packaging tables. But getting a tool steel which could do the job more economically than the grade formerly used was somewhat of a challenge for the manufacturer, J. B. Dove & Sons, Inc., Philadelphia.

The answer was Bethlehem Brake Die, supplied by our local tool steel distributor, Hill-Chase & Co. Because of Brake Die's easy machinability and good wear-resistance, the new die minimized manufacturing costs. It also helped in producing a better-looking product. Said one of the Dove engineers: "We like Brake Die. It's doing a good job for us."

Brake Die, a special alloy steel, is oil-quenched and tempered to develop a fine balance of mechanical properties. It's ideal where wear-resistance, toughness, resistance to impact and good machinability are required.

Typical Analysis

Carbon 0.50	Manganese 0.90
Chromium 1.00	Molybdenum 0.20

Chances are there might be one or more applications in your shop right now where Brake Die steel could be used to good advantage. Why not talk it over with your Bethlehem tool steel distributor?

BETHLEHEM TOOL STEEL ENGINEER SAYS:

How to Shrink-Fit Tool Inserts

Shrink-fitting of tool steel inserts is a procedure which is being widely used to improve the service life of tools. Shrink-fitting is most applicable to rings and cylinders, such as are used in heading and drawing operations where the tools can be shrink-fitted into large retaining rings. The shrink-fit sets up radial compressive stress in the tool, which is available to oppose radial tensile stress set up in service, and thereby improves the performance as compared to solid tools which are not pre-stressed. Shrink-fitting of tools should be carried out as follows:

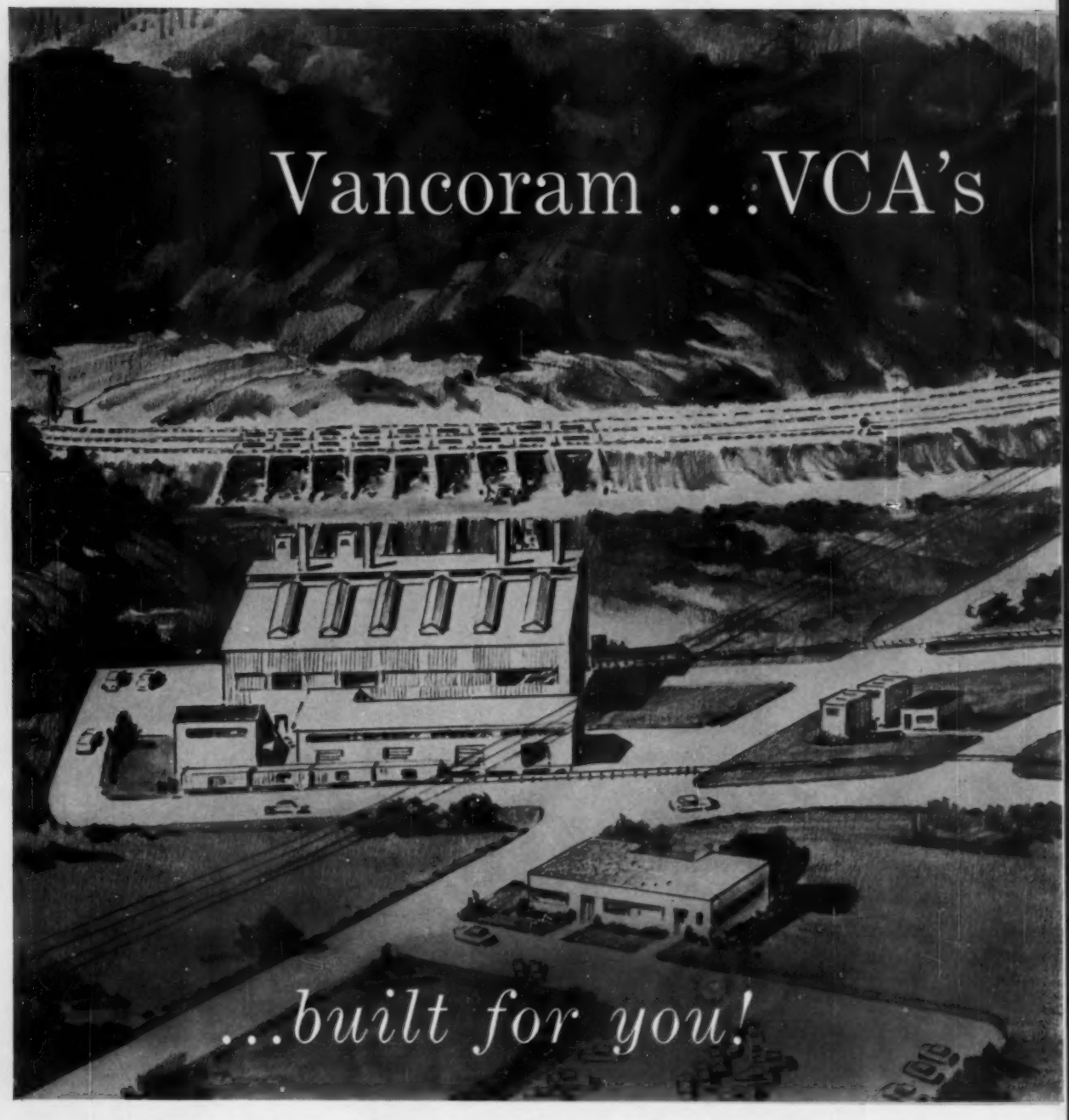
1. The retainer must be of adequate diameter and strength to provide the stresses required on the tool insert. This generally means that an alloy steel capable of hardening to approximately 300/400 BHN must be used. Shock-resisting tool steels heat treated to approximately Rockwell C 48 to 52 are used on heavy duty applications. It is recommended that the OD of the retainer be a minimum of twice the ID (preferably three times the ID).

2. A shrink-fit allowance of .003/.004 in. per in. should be provided for. This means that the OD of the insert is .003/.004 in. per in. larger than the ID of the retainer into which it must fit. These dimensions must be carefully maintained in order to obtain the benefits of shrink-fitting.

3. The OD of the insert and the ID of the retainer should have a smooth finish, preferably produced by grinding.

4. The retainer should be heated to a temperature sufficient to cause the expansion necessary to assemble the insert. Care should be exercised not to exceed the tempering temperature used in heat-treating the retainer. If necessary, the insert may be sub-zero cooled to aid in providing the clearance required for assembly.

5. After assembly of the parts, cooling of the assembly should be rapid enough to prevent over-tempering of the insert by heat transferred from the retainer.



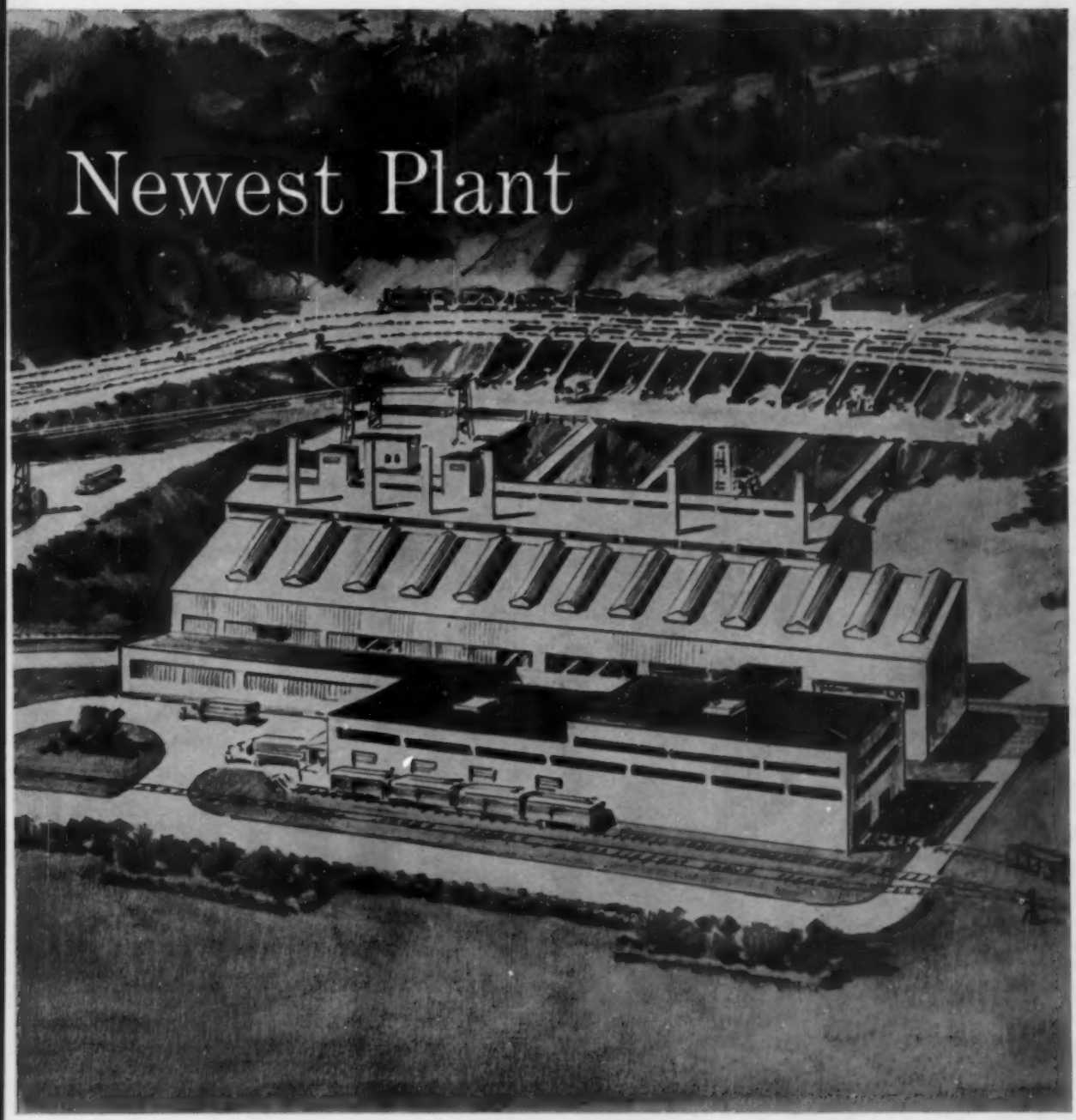
America's stainless steel demands continue to grow. VCA helps meet the need for alloys with giant new plant at Vancoram, Ohio.

Stainless steel production in the U. S. has risen 34% since 1952, when VCA completed its Graham, W. Va., plant devoted to the production of chromium and silicon alloys. To meet America's growing appetite for alloy and stainless steels and irons, VCA is opening these two new plant units in Jefferson County, Ohio—with another unit to come! Products of the new plant will include high carbon ferrochromium, ferrochrome-silicon alloys and Vancoram EXLO®, an extra low carbon ferrochromium of highest purity, extensively used in the production of low carbon stainless.

With this expansion, VCA not only keeps pace with demand, but ahead of it, to assure you of a constant, plentiful and economical source for the alloys that make stainless steel stainless!

Be sure to visit Vancoram Booth # 854, Metals Show, Chicago, Illinois, November 4-8

Newest Plant



This is Vancoram, Ohio. Here, on a 300-acre Jefferson County site, VCA produces chromium and silicon alloys essential to stainless steel production.

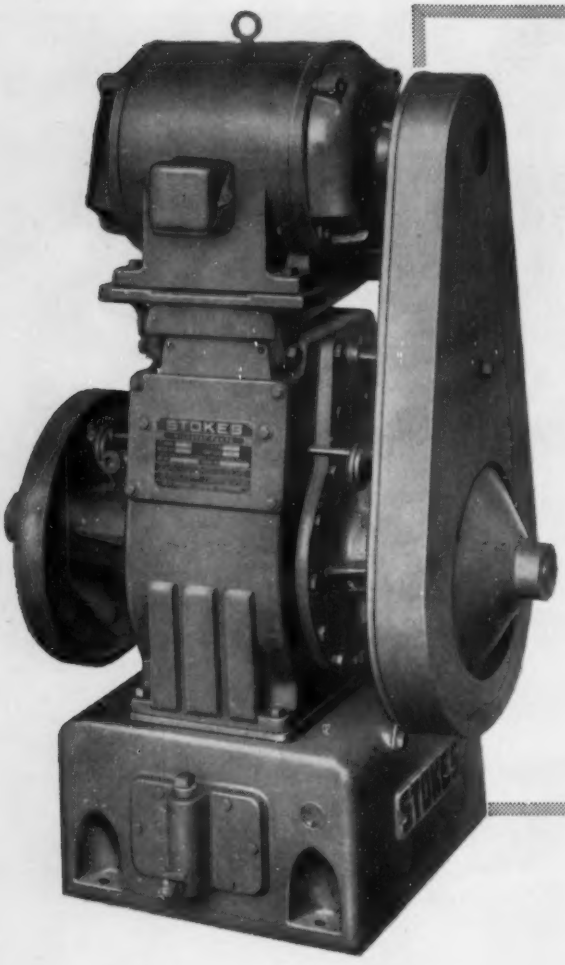
VANCORAM

VANADIUM CORPORATION OF AMERICA

420 Lexington Avenue, New York 17, N.Y.

Chicago • Cleveland • Detroit • Pittsburgh

Producers of alloys, metals and chemicals



VERTICAL DESIGN

vacuum pump saves you floor space

If floor space for your vacuum system installation is a problem, here's an "assist" from Stokes. Special Stokes vertical design cuts floor space requirements. For example, the 130 cfm Model 212 Microvac measures less than 3 feet on a side . . . makes your entire set-up smaller.

And together with these features of compactness, you get a 15% increase in pumping capacity . . . at no increase in price. In this way, Stokes Microvac pumps measure up as the standard of comparison for reliable, low-cost performance.

Here's what you get with the Microvac line:

- Minimum maintenance—mechanical face seal eliminates oil leakage at shaft. No stuffing boxes. Fully automatic lubrication.
- Wide pressure ranges—new exhaust valve design assures trouble-free operation during extended pumping periods, in the high pressure range.
- Dirt troubles prevented—intake screen filter traps dirt, scale and other damaging solids.
- Added protection—new oil filter in the line supplies extra protection to bearings and shaft seal.

Microvac pumps give you the high efficiency you want . . . used separately or as roughing pumps with diffusion or booster pumps. Write for catalog 752, "Stokes Microvac Pumps for High Vacuum"; Booklet 755, "How to Care for Your Vacuum Pump" . . . or call your nearest Stokes office to find out how we can help you solve your particular vacuum application problem.

Vacuum Equipment Division
F. J. STOKES CORPORATION
5500 Tabor Road, Philadelphia 20, Pa.

STOKES

All it takes is practice!

When that ball skims the edge of the cup, you can blame wind, weather, putter, green, your wife's cooking, or a fleeting conflict of ego and libido. But when the shot is sunk, you can credit experience, practice and knowledge of the course. It's the same with titanium.

Titanium can be readily forged, machined, welded, stretched and drawn into shapes having high strength, light weight and superlative resistance to both heat and corrosion. Titanium fabricating, joining and finishing practices are no more difficult than for many other engineering metals, but they are different.

TMCA has accumulated a great deal of pertinent experience and practical data which are available to you on request. Extensive research facilities can also expedite special investigations to answer your specific questions.

TMCA has a selfish reason for helping you "sink the shot" whenever a technical challenge arises. Our Technical Service Department is anxious to discuss your application and cooperate in the establishment of routine fabricating and joining techniques for this outstanding engineering metal . . . now priced competitively.

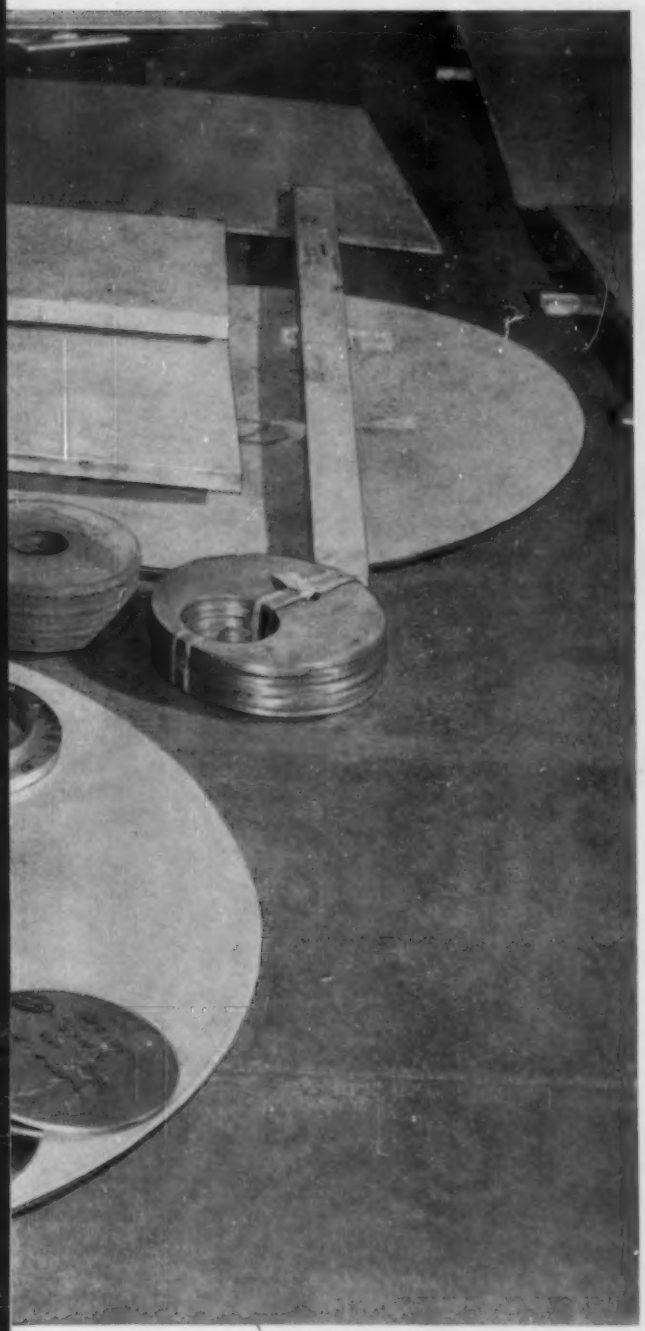
. . . FIRST IN Titanium

TITANIUM METALS CORPORATION OF AMERICA, 233 Broadway, New York 7, N.Y.

12"x 2" Disc or 200"x 132"x 2" Plate

...Carlson is your ONE source for ALL stainless steel components

STAINLESS STEEL PLATES • PLATE PRODUCTS • HEADS • RINGS



Check your drawings and you may find that you require all of the stainless steel items shown here—plates, heads, tube sheets, discs, forgings, flanges, rings, special patterns, bars, and sheets (#1 Finish) in the heavier gauges. When you buy all these material components from one source you save time, effort and money.

Your assembly costs are kept to a minimum when you use Carlson's abrasive cut material. Cleaner edges mean less true-up time on the job. There is no heat-affected zone because little heat is developed during the cutting. Fabrication is easier and the finished product is of the highest quality, more dependable in use.

Who pays freight on "offcuts" you can't use? No one, when you use Carlson's service for cutting plate to shape, ready for your fabrication. Plate is sheared, sawed, flame or abrasive cut and machined to your specifications. Eliminating freight charges on excess material lowers your costs.

There's the matter of delivery which also means time and money to you. As specialists in stainless steels, Carlson has the diversified equipment and the technical and practical knowledge to produce the plate or shapes you want, the way you want them with delivery as promised.

Stainless Steels Exclusively

G. O. CARLSON Inc.

THORNDALE, PENNSYLVANIA

District Sales Offices in Principal Cities

DISCS • FORGINGS • FLANGES • BARS AND SHEETS (No. 1 Finish)

Automatic heat-cycle control protects aircraft engine stamina

Fast, accurate response to temperature or atmosphere change is a vital must in furnace performance at Kelsey-Hayes Company. Precise hardness and shock resistance of aircraft engine parts result from these qualities in two Westinghouse pit furnace and Ammogas® generator installations.

"These Westinghouse pit furnaces are fully automatic," reports the owner. Once the operator sets temperature and atmosphere for each batch, the furnaces maintain temperature control to plus or minus 10°F. For nitriding, a consistently high quality Ammogas atmosphere is supplied each furnace by the 150 cu. ft./hour generator. Varying the atmosphere composition permits bright annealing in the same furnace.

Rigid product specifications are easily met when Westinghouse engineers electric heating equipment. Furnace and atmosphere generators are integrated and test-proven to meet production and metallurgical needs. It's another good reason to talk over your next metal heating problem with the local Westinghouse industrial heating sales engineer, or write Westinghouse Electric Corporation, Industrial Heating Division, Meadville, Pa.

J-10468

All furnace and atmosphere generator sales in the international market are handled by Westinghouse Electric International Company.

YOU CAN BE SURE...IF IT'S Westinghouse

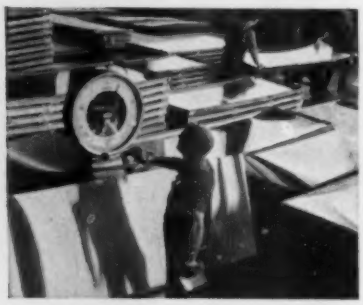
Operating flexibility. Furnaces and Ammogas atmosphere generator handle a wide variety of heating cycle combinations for over fifty different aircraft engine parts. Once heating cycle starts, automatic control takes over.

Single operator economy. One operator easily handles all three Westinghouse electric pit furnaces. They are compact and dependable, providing 15% saving in space and 25% less maintenance than other furnace types.

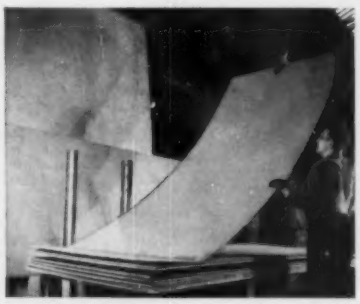
2351

types, shapes, sizes and finishes of Allegheny stainless in stock at Ryerson

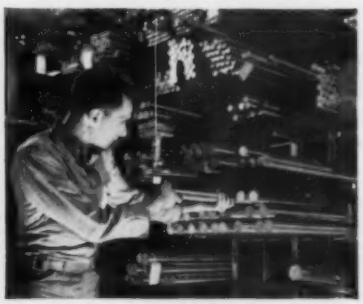
When you want stainless fast . . . anything from one to 2351 types, shapes, sizes and finishes . . . telephone Ryerson. You can depend on accurate processing and quick shipment from Ryerson . . . the nation's oldest supplier of stainless from stock.



STAINLESS SHEETS—Eleven analyses of Allegheny stainless sheets, including nickel and straight chrome types. Extra wide sizes, also, to reduce welding costs. Expanded and perforated sheets.



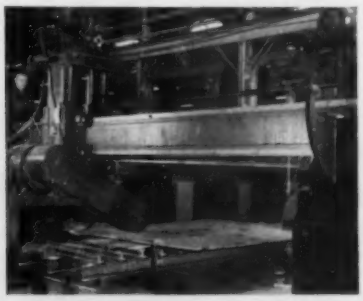
STAINLESS PLATES—Nine analyses, including plates to Atomic Energy Commission requirements and to ASTM specifications for code work. Also extra low carbon types for trouble-free welding.



STAINLESS BARS AND ANGLES — Eight types, including rounds, squares, flats, hexagons and angles. Free-machining bars with both analysis and mechanical properties controlled for best performance.

STAINLESS PIPE AND TUBING—Light wall, standard and extra heavy pipe, ornamental and regular stainless tubing. Also screwed and welding fittings and Cooper stainless valves.

STAINLESS CIRCLES, RINGS, SPECIAL SHAPES—No matter how intricate, we can flame-cut practically any shape from stainless steel plate. One piece or a thousand.



TRUE-SQUARE ABRASIVE CUTTING—Stainless plates up to 12′ x 25′ cut absolutely square on abrasive disc machine. Length and width tolerance plus or minus 1/32″.

Principal products: Carbon, alloy and stainless steel — bars, structurals, plates, sheets, tubing, industrial plastics, machinery and tools, etc.

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JOSEPH T. RYERSON & SON, INC. PLANTS AT: NEW YORK • BOSTON • WALLINGFORD, CONN. • PHILADELPHIA • CHARLOTTE • CINCINNATI • CLEVELAND DETROIT • PITTSBURGH • BUFFALO • INDIANAPOLIS • CHICAGO • MILWAUKEE • ST. LOUIS • LOS ANGELES • SAN FRANCISCO • SPOKANE • SEATTLE

Metal Progress

Volume 72, No. 4 October 1957

THIS YEAR more space is occupied by news of the 39th National Metal Congress and Exposition than ever before in the history of *Metal Progress,* even though it is confined to a mere listing of meetings, speakers and exhibitors. But this is as it must be. In the Congress in Chicago the seven days beginning Saturday, Nov. 2, six other societies are cooperating with the American Society for Metals. To top this, the A.S.M.-sponsored Second World Metallurgical Congress will be holding the final week of its tours through American Industry. Likewise at International Amphitheater in the Metal Exposition, almost 500 firms will show their wares and services – a record in number and in space occupied, and it is safe to predict also in interest and ideas.

In the following pages the program is arranged day by day, as it should be to permit the visitor to choose the items of most interest. The statistics are somewhat staggering: 94 separate technical meetings or discussion groups; 385 prepared papers! While the American Welding Society will not participate (breaking a habit of at least a quarter of a century) the Powder Metallurgy Association is a newly cooperating group. The others who have joined the Congress year after year have a full program. This is especially true of the Society for Nondestructive Testing, which in addition to its regular meetings will be holding its Second International Participation Conference.

This will heighten the international flavor of the Chicago meeting. Each of the eight study tours of the Second World Metallurgical Congress – which will bring together 550 foreign engineers and metallurgical executives – will have two or more informal discussions on topics of importance and of mutual interest to each group of visitors and their American counterparts. These meetings, of course, are open to any interested person. For the group interested in metallurgical aspects of atomic energy the U.S. Atomic Energy Commission has cooperated with the American Society for Metals in arranging eight sessions, four of them comprising a complete consideration of the man-made metal plutonium, on topics held secret before the revision of the declassification guide about six months ago. An idea of the great interest in this new phase of metallurgy can be had from the statistic that almost 25% of the technical and scientific papers to be presented by *all* the cooperating societies in Chicago relate to atomic energy! Appropriately, the ASM will present to the University of Chicago a sculptured memorial commemorating the 15th anniversary of the first chain reaction; the formal presentation will be made on Friday afternoon.

More could be written about various phases of the program, the exposition, the numerous luncheons and banquets, the unexampled opportunity to meet old friends, make new ones, and interchange ideas – but perhaps it can best be summarized by the slogan

COME TO CHICAGO!

National Metal Congress

2nd World Metallurgical Congress

Chicago, Nov. 2 through 8, 1957

American Society for Metals

Headquarters, Palmer House

Seminar on Liquid Metals and Solidification, Saturday and Sunday
Technical Sessions, Monday Through Thursday Afternoon
National Metal Exposition (International Amphitheater), All Week
Educational Course on Precipitation, Monday and Tuesday
Joint Conference with A.E.C. on Plutonium, Monday and Tuesday
Joint Meeting with A.E.C. Internal Group on Welding, Wednesday
Joint Meeting with A.E.C. Group on Metallography, Thursday
Commemoration (15th Anniversary) of Chain Reaction, Friday

2nd World Metallurgical Congress

Headquarters, Sherman Hotel

Reception and First Plenary Session, Sunday
International Panel Discussions, Monday Through Friday
Farewell Banquet, Friday

The Metallurgical Society of American Institute of Mining, Metallurgical and Petroleum Engineers

Headquarters, Morrison Hotel

Institute of Metals Division, Monday Through Thursday
Iron and Steel Division, Tuesday and Wednesday Morning

Society for Nondestructive Testing

Headquarters, Morrison Hotel

Technical Sessions, Monday Through Friday
Second International Conference on Nondestructive Testing, Sunday Afternoon Through Friday
Educational Sessions, Thursday

Industrial Heating Equipment Association

(Jointly With ASM)

Technical Session on Tuesday Morning

Powder Metal Association

(Jointly With ASM)

Technical Session, Thursday Afternoon

Special Libraries Association, Metals Division

Headquarters, Knickerbocker Hotel

Technical Sessions and Field Trips, Wednesday Through Friday

Complete programs, grouped by days, shown on following pages

Saturday, Nov. 2, 1957

9:00 A.M. Palmer House

Seminar on
Liquid Metals and Solidification

Theory and Structure of Liquids
By *G. Vineyard*, Brookhaven National Laboratory

Properties of Liquid Metals
By *N. H. Hachtrieb*, University of Chicago

Thermodynamics and Properties of Liquid Solutions
By *O. J. Kleppa*, University of Chicago

2:00 P.M. Palmer House

Seminar on
Liquid Metals and Solidification

Nucleation
By *E. M. Pound*, Carnegie Institute of Technology

Solid-Liquid Reactions
By *J. Weeks* and *D. H. Gurinsky*, Brookhaven National Laboratory

Mechanism of Metal Electrodeposition
By *J. O'M. Bockris*, Univ. of Pennsylvania

Sunday, Nov. 3

9:00 A.M. Palmer House

Seminar on
Liquid Metals and Solidification

Mechanism of Crystal Growth
By *K. A. Jackson*, Harvard University

Thermal Considerations in Freezing
By *C. M. Adams, Jr.*, Massachusetts Institute of Technology

Solute Redistribution During Freezing
By *W. G. Pfann*, Bell Telephone Labs.

2:00 P.M. Palmer House

Seminar on
Liquid Metals and Solidification

Imperfections Resulting from Solidification
By *John Rutter*, General Electric Co.

Polyphase Solidification
By *William A. Tiller*, Westinghouse Electric Corp.

Structure of Ingots and Castings
By *J. Walker*, General Electric Co.

2:00 P.M. Morrison Hotel

International Participation Conference

International Cooperation in the Field of Nondestructive Testing

4:00 P.M. Sherman Hotel

Reception to Foreign Conferees and American Counterparts

8:00 P.M. Palmer House

First Plenary Session
A Preview of Tomorrow's Metallurgy

Mineral and Energy Resources of the Free World
By *John Reedman*, United Nations' Organization

The Future of Iron and Steel Making

The Future of Nonferrous Metallurgy
By *Francis C. Frary*, Aluminum Co. of America

Future Fabrication Techniques
By *Manuel C. Sanz*, North American Aviation, Inc.

The Future of Heat Treatment
By *Otto Schaaber*, Bremen, St. Magnus (Germany)

The Role of the Metal Engineer in Nuclear Power
By *R. A. Skinner*, A.E.I.-John Thompson Nuclear Energy Co., Ltd. (England)

Summary
By *Zay Jeffries*, Director General, 2nd World Metallurgical Congress

Monday Morning, Nov. 4

9:00 A.M. Palmer House

First Session on Steel

Electrolytic Extraction of Carbides From Carbon Steel
By *R. W. Curry,* Quaker Chemical Co., *J. Christakos,* W. M. Kellogg Co., and *C. D. Stricker,* U.S. Steel Corp.

Transformation Structures in Hypoeutectoid Alloy Steels
By *W. C. Hagel* and *M. N. Ruoff,* General Electric Co.

Effect of Manganese on the Curie Point of Cementite
By *Earl C. Roberts,* Univ. of Washington

Morphological and Phase Changes During Quench-Aging of Ferrite Containing Carbon and Nitrogen
By *G. Lagerberg,* Stora Kopparbergs Bergslags Aktiebolag (Sweden), and *B. S. Lement,* Mass. Institute of Technology

Some Relationships Between Torsional Strength and Electron Microstructure In a High-Carbon Steel
By *S. T. Ross, R. P. Sernka* and *Walter E. Jominy,* Chrysler Corp.

9:00 A.M. Palmer House

Session on Zirconium

The Powder Metallurgy of Zirconium-Uranium Alloys
By *Herbert S. Kalish,* Sylvania Electric Products, Inc.

A Hot-Hardness Survey of the Zirconium-Uranium System
By *W. Chubb,* Battelle Memorial Institute, *G. T. Muehlenkamp,* General Electric Co., and *A. D. Schwope,* Clevite Research Center

Transformation Kinetics of Zirconium-Uranium Alloys
By *D. L. Douglass, L. L. March* and *G. K. Manning,* Battelle Memorial Institute

Transformation Kinetics and Mechanical Properties of Zirconium-Titanium and Zirconium-Tin Alloys
By *R. F. Domagala, D. W. Levinson* and *D. J. McPherson,*
Armour Research Foundation

9:00 A.M. Palmer House

Conference on the Metal Plutonium
(Jointly With Atomic Energy Commission)

Historical Review

Discovery of Plutonium in the Cyclotron
By *Glenn T. Seaborg,* Univ. of California

Isolation of Plutonium
By *B. B. Cunningham,* Univ. of California

Research on the Metallurgy of Plutonium at Chicago Metallurgical Laboratory
By *Sherman Fried,* Argonne National Laboratory

Early Work at Los Alamos
By *Cyril Stanley Smith,* University of Chicago

Later Plutonium Metallurgical Research at Los Alamos
By *Arthur S. Coffinberry,* General Chairman of Conference, Los Alamos Lab., A.E.C.

Plutonium Metallurgy at Hanford
By *O. J. Wick,* Hanford Atomic Products Operation

Plutonium Metallurgy at Argonne National Laboratory
By *Frank G. Foote,* Argonne National Laboratory

Studies on Plutonium at Chalk River
By *O. J. C. Runnalls,* Atomic Energy of Canada, Ltd.

Plutonium Metallurgical Studies in Great Britain
By *H. M. Finniston,*
U. K. Atomic Energy Research Establishment, Harwell (England)

Plutonium Metallurgy in France
By *E. Grison,* Atomic Energy Commission, Saclay (France)

9:00 A.M. Sherman Hotel

Panel Discussion; Group 4; Heat Treatment

Topic: Carburizing

Moderator: *Walter Holcroft*, Holcroft & Co.
Panel Members:

Bernard Jousset, Ste. Parisienne de Cementation (France)
N. O. Kates, Lingberg Steel Treating Co.
W. Stuhlmann, International Business Machines (Germany)
T. A. Frischman, Eaton Mfg. Co.
J. H. Evans, British Timken, Ltd.
O. E. Cullen, Surface Combustion Corp.
Birger Lineberg, Kopings Nekaniska Verkstads A.G. (Sweden)
Masuo Kawakami, Tokyo Institute of Technology (Japan)

9:00 A.M. Sherman Hotel

Panel Discussion; Group 5; Welding & Joining

Topic: Ship Welding

Moderator: *D. P. Brown*, American Bureau of Shipping
Panel Members:

J. Hargreaves, United Steel Companies, Ltd. (England)
A. G. Hogaboom, Bethlehem Shipbuilding Div.
Walther Dick, Huttenwerk Oberhausen (Germany)
A. A. Holzbauer, Sun Shipbuilding & Drydock Co.
Tadamasa Matsuoka, Uraga Dock Co., Ltd. (Japan)
E. M. McCutcheon, Office of Naval Research

9:00 A.M. Morrison Hotel

International Participation Conference

The Basis for Selection of Optimum Test Methods

a. Definition of Terms
b. Analysis of Specific Problems
c. Logical Subdivisions of Test Methods
d. Parameters Leading to Optimum Methods

Keynote Speakers:

James Thewlis, Atomic Energy Research Establishment (England)
Prof. Georges A. Homes, Faculte Polytechnique de Mons and Universite Libre de Bruxelles (Belgium)
Don M. McCutcheon, Westinghouse Atomic Power Division

Invited Discussor:

S. A. *Wenk*, University of California, Radiation Laboratory

9:00 A.M. Morrison Hotel

Session on Deformation

Effect of Deformation and Low Temperatures on the Structures of AgCd and AuZn
By *D. B. Masson* and *C. S. Barrett*, University of Chicago

Role of Rate-History in the Calculation of Creep Behavior
By *J. D. Lubahn*, General Electric Co.

Temperature Dependence of the Yield Stress for Copper and Aluminum
By *W. D. Sylwestrowicz*, Bell Telephone Laboratories

Grain Boundry Deformation in Fine-Grained Electrolytic Magnesium
By *S. L. Couling*, Dow Chemical Co., and *C. S. Roberts*, Shockley Semi-conductors Laboratory

Activation Energies for Creep of Single Aluminum Crystals
By *J. Lytton*, *L. Shepard* and *J. E. Dorn*, University of California

Size Effects in the Deformation of Bi-crystals and Single Crystals of Aluminum
By *R. L. Fleischer* and *Bruce Chalmers*, Harvard University

Abrupt Yielding and the Ductile-to-Brittle Transition in Body Centered Cubic Metals
By *E. T. Wessel*, Westinghouse Electric Corp.

Effect of Strain and Temper Embrittlement on the Impact Transition Temperature of an A.I.S.I. E-6150 Steel
By *E. F. Steeb*, North American Aviation and *P. C. Rosenthal*, Univ. of Wisconsin

9:00 A.M. Morrison Hotel

Symposium on the Relation of Structure and High-Temperature Properties

Nature of Aging of Fe-Cr Alloys at 500° C.
By *M. J. Marcinkowski* and *R. M. Fisher*, U.S. Steel Corp.

Influence of Structures in Low-Alloy Steels on the High-Temperature Properties
By *L. Habraken*, Centre National de Recherches Metallurgiques (Belgium)

Evolution of Aging Structures During High-Temperature Exposure
By *W. C. Hagel* and *H. J. Beattie, Jr.*, General Electric Co.

Phase Changes in an Age-Hardenable Ni-Fe-Cr Alloy During Prolonged Heating
By *C. C. Clark* and *J. S. Iwanski*, International Nickel Co.

Structure and Property Studies in Ni-Cr-Al Solid Solution, Dispersion Hardened
By *J. H. Westbrook*, General Electric Co.

Electron Microstructure of an Age-Hardenable Ni-Cr Alloy
By *K. G. Carrol* and *J. R. Mihalisin* International Nickel Co.

Fundamental Influence of Cobalt in Heat Resisting Steels
By *W. Siegfried*, *W. Bollmann*, *B. Lux* and *H. Nohl*, Battelle Memorial Institute, Geneva (Switzerland)

Monday Morning, Nov. 4

(Continued)

9:30 A.M. Palmer House

Educational Lecture Series on Precipitation From Solid Solution

Introductory and Summary Lectures
By *R. F. Mehl*,
Carnegie Institute of Technology

General Theory, Mechanism and Kinetics
By *J. B. Newkirk*, General Electric Co.

Precipitation Hardening Aluminum-Base Alloys
By *W. A. Anderson*,
Alcoa Research Laboratories

9:00 A.M. Morrison Hotel

Seminar on Structure of Solid Solutions

Elastic Constants of Solid Solutions
By *C. S. Smith*,
Case Institute of Technology

Resistance Anomalies in Dilute Alloys
By *R. W. Schmitt*, General Electric Co.

Nuclear Magnetic Resonance in Metals and Alloys
By *T. J. Rowland*,
Electro Metallurgical Co.

9:00 A.M. Morrison Hotel

Structures and Properties of Metals and Alloys

Preferred Orientations in Castings
By *Derek Walton* and *Bruce Chalmers*, Harvard University

Ductility in Beryllium Related to Grain Orientation and Grain Size
By *J. Greenspan*, Nuclear Metals, Inc.

Effects of Various Preferred Orientations on the Dimensional Stability of Uranium
By *W. V. Cummings*, General Electric Co.

Dimensional Stability of Uranium-Chromium Alloy
By *M. C. Fraser*, *G. A. Last*, and *S. H. Bush*, General Electric Co.

A Study of the Effect of Reactor Irradiation on the Microstructure of Uranium
By *T. K. Bierlein* and *B. Mastel*, General Electric Co.

Irradiation Effects on the Tensile Properties of Zircaloy-2
By *R. S. Kemper, Jr.*, and *D. L. Zimmerman*, General Electric Co.

Brittleness and the Thermal Expansion Behavior of Titanium Carbide Base Cermets
By *H. W. Newkirk, Jr.*, General Electric Co., and *H. H. Sisler*, Ohio State University.

Estimation of Coefficients for the Reactive Diffusion of Carbon in Zirconium Carbide
By *E. Hirakis* and
M. A. Steinberg, Horizons, Inc.

Surface Tension of Silver-Gold and Copper-Gold Solid Solutions
By *S. S. White*, *C. M. Adams, Jr.*, and *J. Wulff*, Mass. Institute of Technology.

Autoradiographic and Metallographic Evidence for a Metallic Second Phase in High-Purity Zinc
By *I. S. Servi*, *M. Stern*, and *W. W. Webb*, Electro Metallurgical Co., Div. of Union Carbide Corp.

Monday Noon

12:00 M. International Amphitheater — 39th Annual Metal Exposition Opens

Monday Afternoon, Nov. 4

2:00 P.M. Palmer House

Second Session on Steel

Some Aspects of the Morphology and Chemistry of Lead in Leaded High-Sulphur Steels
By *J. W. Thurman* and *E. J. Paliwoda*, Jones & McLaughlin Steel Corp., and *E. J. Duwell*, Minnesota Mining & Mfg. Co.

The Distribution of Residual Stresses in Carburized Cases and Their Origin
By *D. P. Koistinen*, General Motors Corp.

The Effect of Percentage of Tempered Martensite on Endurance Limit
By *F. Borik, R. D. Chapman* and *W. E. Jominy*, Chrysler Corp.

The Machinability of Type A Leaded Steels
By *E. J. Paliwoda*,
Jones & Laughlin Steel Corp.

2:00 P.M. Palmer House

Session on Titanium

Grain Growth and Recrystallization of Commercial Titanium and Ti-100A Alloy
By *E. L. Bartholomew*,
University of Connecticut

Mechanical Properties and Heat Treatment of Titanium-Columbium Alloys
By *L. W. Berger, D. N. Williams* and *R. I. Jaffee*, Battelle Memorial Institute

Evaluation of a New Titanium-Base Sheet Alloy, Ti-4 Al-3 Mo-1 V
By *R. S. Richards, D. L. Day* and *H. D. Kessler*, Titanium Metals Corp. of America

Mechanical Properties Correlated With Transformation Characteristics of Titanium-Vanadium Alloys
By *E. L. Harmon* and *A. R. Troiano*, Case Institute of Technology, and *J. Kozol*, Combustion Engineering, Inc.

Factors Affecting the Absorption and Distribution of Hydrogen in Titanium During Acid Pickling
By *C. R. McKinsey, M. Stern* and *R. A. Perkins*, Electro Metallurgical Co.

The Mode of Hydride Precipitation in Alpha Titanium and Alpha Titanium Alloys
By *Tien-Shih Liu*,
Titanium Metals Corp. of America
and *M. A. Steinberg*, Horizons, Inc.

2:00 P.M. Palmer House

Conference on the Metal Plutonium
(Jointly With Atomic Energy Commission)

Role of Plutonium in Nuclear Power

General Statement
By *R. M. Kiehn*, Los Alamos Laboratory

Concepts Employing Solid Fuel Elements
By *Frank G. Foote*, Argonne National Laboratory

Plutonium Fuels for Power Reactors
By *S. F. Pugh*, U.K. Atomic Energy Authority (England)

Fluid Fueled, Fast Power Reactor Concept
By *Russell E. L. Stanford*, Atomic Power Development Assoc., Inc.

"Lampre" (Molten Plutonium) Concept
By *David Hall*, Los Alamos Laboratory

Liquid Metal Fuel Reactor (LMFR)
By *David Gurinsky*, Brookhaven National Laboratory

Mixed-Oxide Concept
By *W. M. Cashin*, Knolls Atomic Power Laboratory

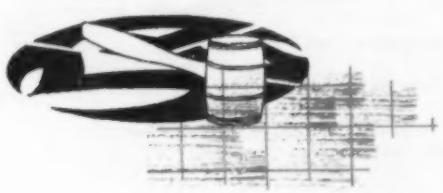
The Hanford Plutonium Re-cycle Reactor Concept
By *R. M. Fryar*, Hanford Atomic Products Operation

2:00 P.M. Palmer House

Educational Lecture Series on Precipitation From Solid Solution

Precipitation Reactions in Irons and Low-Alloy Steels
By *H. W. Paxton*,, Carnegie Institute of Technology

Precipitation in Iron-Base Alloys
By *Adolph J. Lena*, Allegheny Ludlum Steel Corp.



Monday Afternoon, Nov. 4

2:00 P.M. Sherman Hotel

Panel Discussion; Group 4; Heat Treatment

Topic: Minimizing Distortion

Moderator: *H. N. Bosworth,* H. N. Bosworth Steel Treating Co.

Panel Members:

Otto Schaaber, Institute fur Harterei-Technik (Germany)
D. J. Wright, Caterpillar Tractor Co.
Olle Liedholm, A. B. Volo (Sweden)
W. T. Groves, Dana Corp.
Frank P. Heard, Coote & Jorgensen, Ltd. (Australia)
George Bidigare, Commercial Steel Treating Corp.

2:00 P.M. Sherman Hotel

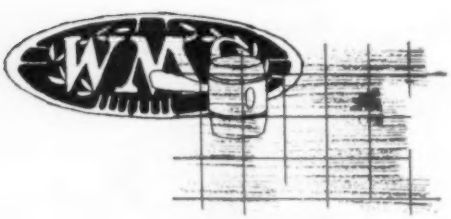
Panel Discussion; Group 5; Welding and Joining

Topic: Electrodes

Moderator: *D. C. Smith,* Harnischfeger Corp.

Panel Members:

Bjorn Kjellberg, Elektriska Svetsnings A.B. (Sweden)
O. T. Barnett, Armour Research Foundation
Veikko Valanti, OY ESAB, Pitajanmaki (Finland)
R. K. Lee, Alloy Rods Co.
Hiroshi Kihara, Tokyo University (Japan)
W. H. Wooding, Philadelphia Navy Yard



2:00 P.M. Morrison Hotel

International Participation Conference

The Basis for Selection of Optimum Test Methods

(Continued From Morning)

2:00 P.M. Morrison Hotel

Titanium Metallurgy

Phase Transformations in Hypoeutectoid Titanium-Chromium Alloys
By *H. I. Aaronson, W. B. Triplett* and *G. M. Andes,* Carnegie Institute of Technology

Notch Tensile Properties of Selected Titanium Alloys
By *E. P. Klier,* Syracuse University, and *N. J. Feola,* Curtiss-Wright Corp.

Effect of Hydrogen on the Fatigue Properties of Titanium and Ti-Mn Alloys
By *L. W. Berger, W. S. Hyler* and *R. I. Jaffee,* Battelle Memorial Institute

Hydrogen Distribution in Heat Treated Titanium Alloys as Established by Auto-Radiography
By *O. J. Huber, J. E. Gates, A. P. Young, M. Poberskin* and *P. D. Frost,* Battelle Memorial Institute

Hydrogen Solubility and Removal for Titanium and Titanium Alloys
By *W. M. Albrecht* and *M. W. Mallett,* Battelle Memorial Institute

Effect of Crystallographic Orientation and Oxygen Content on Knoop Hardness Values of Iodide Titanium
By *C. Feng* and *C. Elbaum,* University of Toronto

Effect of Hydrogen on Some Mechanical Properties of a Titanium Alloy Heat Treated to High Strength
By *H. A. Robinson, P. D. Frost* and *W. M. Parris,* Battelle Memorial Institute

Reorientation Textures Developed by Isothermally Annealing Cold Rolled Iodide Titanium
By *C. J. Sparks, Jr.,* Wright Air Development Center, and *J. P. Hammond,* Oak Ridge National Laboratory

2:00 P.M. Morrison Hotel

Deformation and Oxidation

Hydrogen, Crack Initiation, and Delayed Failure in Steel
By *H. H. Johnson, J. G. Morlet,* and *A. R. Troiano,* Case Institute of Technology

Fracture of Zinc Monocrystals and Bicrystals
By *J. J. Gilman,* General Electric Co.

Temperature Dependence of Flow and Fracture in Coated Zinc Single Crystals
By *L. C. Weiner,* Columbia University

Pyramidal Slip in Magnesium
By *R. E. Reed-Hill* and *W. D. Robertson,* Yale University

Grain Boundary Shear in Aluminum
By *F. Weinberg,* Department of Mines and Technical Surveys, Ottawa, Ont.

Delay Time in Face-Centered Cubic Metals
By *I. R. Kramer* and *H. R. Peiffer,* Rias, Inc.

Work Hardening on the Latent Slip Directions of Alpha-Brass During Easy Glide
By *W. L. Phillips* and *W. D. Robertson,* Yale University

Impurity Substructures in Zinc Single Crystals
By *H. G. F. Wilsdorf,* Franklin Institute

Oxidation of Zircaloy-2 and 3A at 300 to 850° C.
By *E. A. Gulbransen* and *K. F. Andrew,* Westinghouse Electric Corp.

Structural Aspects of the Corrosion of Stainless Steel at 500 to 700° C. in Gaseous Atmospheres
By *E. A. Gulbransen, T. Copan* and *D. van Rooyen,* Westinghouse Electric Corp.

Fabrication of Uranium Dioxide Fuel Element Shapes by Hydrostatic Pressing
By *H. W. Newkirk, Jr.,* and *R. J. Anicetti,* General Electric Co.

2:00 P.M. Morrison Hotel

Symposium on the Relation of Structure and High-Temperature Properties

Influence of Carbon and Nitrogen on Creep and Creep-Rupture Properties and Structure of 18-8 Cr-Ni Steels, With and Without Molybdenum
By *G. V. Smith,* Cornell University, *F. Garofalo and L. Zwell,* U.S. Steel Corp.

Effect of Interstitial Elements on the Properties of Cr-Mn-N-C Steels
By *Chi-Mei Hsiao* and *E. J. Dulis,* Crucible Steel Co. of America

Microstructural Changes in a 42-30-25 Ni-Cr-Fe Alloy During Creep-Rupture Testing
By *E. P. Sadowski* and *R. J. Raudebaugh,* International Nickel Co.

Nickel-Chromium Base Alloys Hardened With Refractory Oxide Additions
By *A. W. Cochardt,* Westinghouse Electric Corp.

Contribution of Spherical and Platelike Precipitate Particles to Creep and Tensile Strength
By *E. E. Underwood,* Battelle Memorial Institute

Creep and Structure Studies of Two-Phase Aluminum-Copper Alloys
By *R. Pelloux, A. R. Chaudhuri* and *N. J. Grant,* Mass. Institute of Technology

2:00 P.M. Morrison Hotel

Research Summaries on Structure of Solid Solutions

Solubility of Hydrogen in Thorium Metal
By *D. T. Peterson* and *D. G. Westlake,* Iowa State College.

Free Energy Changes Attending the Martensitic Transformation in the Fe-Cr and Fe-Cr-Ni Systems
By *Larry Kaufman,* Massachusetts Institute of Technology.

Calculation of Entropies of Solute Atoms From Solid Solubilities
By *J. F. Freedman,* Yale University, and *A. S. Nowick,* Columbia University

Elastic Interaction of Interstitial Atoms in Body-Centered Cubic Crystals
By *J. C. Fisher,* General Electric Co.

Misfit Strain Energy in the Gold-Copper System
By *Ralph Hultgren,* Univ. of California

An Acoustical Study of Low-Temperature Aging in Al-4.2 Cu
By *M. E. Fine* and *C. Chiou,* Northwestern University.

Alloying Behavior of Ni_3Al (γ'-Phase)
By *R. W. Guard* and *J. H. Westbrook,* General Electric Co.

Tuesday Morning, Nov. 5

9:30 A.M. Palmer House

Mechanical Properties of Steel

Strain Hardening of Austenitic Stainless Steel
By *G. W. Powell*, Nuclear Metals, Inc., *E. R. Marshall*, University of Vermont, and *W. A. Backofen*, Massachusetts Institute of Technology

The Effect of Rate of Stress Application and Temperature on the Upper Yield Stress of Annealed Mild Steel
By *J. A. Hendrickson* and *D. S. Wood*, California Institute of Technology

Some Aspects of Pre-Yield Phenomena in Mild Steel at Low Temperatures
By *W. S. Owen, Morris Cohen* and *B. L. Averbach*, Massachusetts Institute of Technology

The Energy Stored in Ingot Iron Deformed by Torsion at +25 −82 and −185° C.
By *T. P. Wang*, Wilbur B. Driver Co., and *Norman Brown*, University of Pennsylvania

9:30 A.M. Palmer House

Session on Metallography

Classification of Precipitation Systems
By *R. O. Williams*, Cincinnati Milling Machine Co.

A Method for Etching Metals by Ion Bombardment
By *John B. Newkirk* and *W. G. Martin*, General Electric Co.

The Relation Between Constitution and Ultimate Grain Size in Aluminum Alloy 3003
By *Philip R. Sperry*, Kaiser Aluminum & Chemical Corp.

The Occurrence of Laves-Type Phases Among Transition Elements
By *R. P. Elliott* and *W. Rostoker*, Armour Research Foundation

9:30 A.M. Palmer House

Conference on the Metal Plutonium

(Jointly With Atomic Energy Commission)

Physical Properties of Plutonium Metal

Preparation of High-Purity Metal
By Argonne Laboratory Representative

Physical Properties of Plutonium Studied at U.K. Atomic Energy Research Establishment
By *J. A. Lee* and *P. G. Mardon*, Harwell (England)

Some Physical and Physico-Chemical Properties of Plutonium Studied at U.K. Atomic Weapons Research Establishment
By *A. E. Kay* and *W. B. H. Lord*, Aldermaston (England)

Some Mechanical Properties of Plutonium
By *H. R. Gardner*, Hanford Atomic Products Operation

First French Studies on French-Made Plutonium Metal
By *R. Abramson, F. Anselin, R. Boucher, R. Fabre, H. Monti* and *R. Pascard*, Saclay (France)

Dilatometry and Thermal Analysis
By *E. M. Cramer*, Los Alamos Laboratory

Sound Velocity Measurements
By *H. L. Laquer*, Los Alamos Laboratory

Measurement of Diverse Physical Properties
By *T. A. Sandenaw*, Los Alamos Laboratory

Crystal Structure
By *W. H. Zachariasen*, University of Chicago

Delta-Prime Phase
By *R. O. Elliott*, Los Alamos Laboratory

The Corrosion of Plutonium
By *J. T. Waber*, Los Alamos Laboratory

Radiography and Auto-Radiography of the Metal and Its Alloys
By *G. H. Tenney*, Los Alamos Laboratory

Summary and Review
By *A. S. Coffinberry*, Los Alamos Laboratory

9:00 A.M. **Sherman Hotel**

Panel Discussion; Group 3; Metal Fabrication

Topic: Steel Gears

Moderator: *M. F. Gardwood,* Chrysler Corp.

(a) Selection of Steel
By *Harry B. Knowlton,* Armour Research Foundation

(b) Fabrication
By *Aldo Zazzaroni,* FIAT (Italy), and *T. A. Frischman,* Eaton Mfg. Co.

(c) Problems in Operation
By *H. Sigwart,* Daimler-Benz A.G. (Germany), and *R. L. Mattson,* General Motors Corp.

9:00 A.M. **Morrison Hotel**

Nondestructive Testing of Nuclear Power Reactor Components

Nondestructive Testing of Fuel Elements for DIDO
By *J. Thewlis,* Atomic Energy Research Establishment (England)

The Fundamentals of Differential Radiation Measurements
By *Richard A. Nickerson,* Sandia Corp.

NRU—Some of Its Special Testing Problems
By *A. J. Mooradian,* Atomic Energy of Canada, Ltd.

Dimensional Measurements Using Nondestructive Testing Techniques
By *Bernard Cunningham,* Westinghouse Electric Corp., Atomic Fuel Dept.

9:00 A.M. **Morrison Hotel**

Recent Developments in Steelmaking Practices

Properties and Performance of Continuously Cast Low-Carbon Steel Products
By *R. N. Edmonson, L. Mair* and *M. Tenenbaum,* Inland Steel Co.

Nitrogen Control and Nitrogen Content of Steels
By *K. G. Speith* and *H. vom Ende,* Mannesmann-Huttenwerke (Germany)

Vacuum Arc Melting
By *E. W. Johnson,* Westinghouse Electric Corp.

Observations of the Russian Steel Industry
By *N. J. Grant,* Massachusetts Institute of Technology

9:00 A.M. **Morrison Hotel**

Nonferrous and High-Temperature Alloys

Sand Cast Alloys of Magnesium-Rare Earth Metal-Zirconium Alloys
By *T. E. Leontis,* Dow Chemical Co., and *D. H. Feisel,* Carnegie Institute of Technology

Blister Formation in Rolled Aluminum
By *J. H. O'Dette,* Aluminum Laboratories, Ltd. (Canada)

On the Release of Hydrogen From Molten Aluminum
By *Asutosh Pal,* Aunapurna Metal Works (India), and *H. M. Davis,* Pennsylvania State University

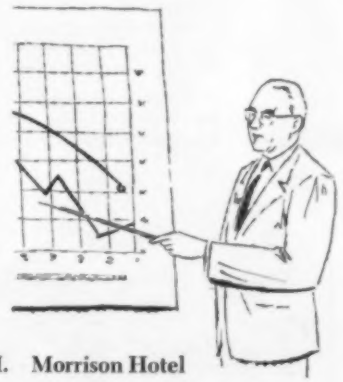
Elastic Properties of Yttrium and Eleven of the Rare Earth Elements
By *J. F. Smith, C. E. Carlson* and *F. H. Spedding,* Iowa State College

Gas Desorption of Copper Powders
By *J. C. Tobin,* General Electric Co., and *M. J. Sinnott,* University of Michigan

Copper-Silica and Copper-Alumina Alloys of High-Temperature Interest
By *K. M. Zwilsky* and *N. J. Grant,* Massachusetts Institute of Technology

Nitrides in Chromium
By *I. S. Servi* and *W. D. Forgeng,* Electro Metallurgical Co.

Determination of Orientation in Magnesium by Polarized Light
By *C. W. Pearsall* and *S. J. Couling,* Dow Chemical Co.



9:00 A.M. **Morrison Hotel**

Seminar on Science of Metal Hardening

Effect of Alloying on High-Temperature Creep Properties
By *J. Weertman,* U. S. Naval Research Laboratory

Magnetic Study of Precipitation Hardening
By *J. D. Livingston,* General Electric Co.

Strength of Age-Hardened Alloys
By *A. Kelly,* Northwestern University

Nonhomogeneous Deformation in the Austenite-Martensite Transformation
By *D. S. Lieberman,* University of Illinois

Tuesday Morning, Nov. 5

9:00 A.M. Palmer House

Joint Session With ⚙ on Modern Techniques

Modernization in Heating for Hot Forming
By *P. H. Morse,* Magnethermic Corp.

The Metallurgy of Annealing in Fractional Minutes
By *R. K. Wuerfel,* Westinghouse Electric Corp.

Techniques and Metallurgy of Induction Vacuum Melting
By *Walter Jones,* General Electric Co.

Convection and Radiation in High Speed Heating
By *R. J. Reed,* North American Mfg. Co.

Influence of High Speed Strip Annealing on Metallurgical Properties
By *Gilbert J. Langenderfer,*
Surface Combustion Corp.

Automation in Heating and Quenching
By *N. K. Koebel,*
Lindberg Engineering Co.

9:00 A.M. Morrison Hotel

Symposium on Titanium

Moderator: *L. S. Busch,* Mallory-Sharon Titanium Corp.

Keynote Speaker: *John Garrett,* Office of Assistant Secretary of Defense for Research and Development

United States' Progress in Titanium, 1956 and 1957
By *W. J. Harris, Jr.,* Minerals and Metals Advisory Board, National Academy of Science—National Research Council

European Progress in Titanium

9:00 A.M. Palmer House

Educational Lecture Series on Precipitation From Solid Solution

Precipitation in Copper Alloys
By *William D. Robertson,* Yale University

Precipitation Reactions in Magnesium Alloys
By *R. S Busk,* Dow Chemical Co.

Tuesday Noon

12:00 M. Palmer House

Annual Awards Luncheon

Speaker: *Joel Hunter,* President and Chief Executive Officer, Crucible Steel Co. of America

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Tuesday Afternoon, Nov. 5

1:30 P.M. Morrison Hotel

Mehl Honor Lecture

Mottling in Radiographs of Al-Si-Cu Permanent Mold Castings
By *Kent R. Van Horn*, Aluminum Co. of America

S.N.T. Annual Meeting

2:00 P.M. Palmer House

Educational Lecture Series on Precipitation From Solid Solutions

Some Age Hardening Characteristics of Nickel-Chromium Alloys (Nickel-Rich) Containing Aluminum and Titanium
By *R. J. Raudebauch* and *Clarence Bieber*, International Nickel Co.

Precipitation in Cobalt-Base Alloys
By *Glenn A. Fritzlen*, Haynes Stellite Co.

2:00 P.M. Palmer House

Conference on the Metal Plutonium
(Jointly With Atomic Energy Commission)

Plutonium Alloys and Fuel Elements

Phase Diagrams Studied at Harwell
By *M. B. Waldron*, U.K. Atomic Energy Authority (England)

Phase Diagrams Studied at Los Alamos
By *F. W. Schonfeld*,
Los Alamos Laboratory

Phase Diagrams Published by Russians
By *F. W. Schonfeld*,
Los Alamos Laboratory

Review of Intermetallic Compounds
By *F. H. Ellinger*, Los Alamos Laboratory

Aluminum-Plutonium Elements for MTR
By *R. E. Tate*, Los Alamos Laboratory

Plutonium Alloy Preparation at Chalk River
By *O. J. C. Runnalls*, Atomic Energy of Canada, Ltd.

Fabrication of Al-Pu Elements for NRX
By *K. L. Wauchope*, Atomic Energy of Canada, Ltd.

Studies of Other Fuel Elements Containing Plutonium
By *L. R. Kelman*, Argonne National Laboratory

2:00 P.M. Palmer House

Session on Brittle Fracture

Brittle Fracture of Mild Steel in Tension at -196^{0} C.
By *W. S. Owen*, *Morris Cohen* and *B. L. Averbach*, Mass. Institute of Technology

The Initiation of Brittle Fracture in Mild Steel
By *J. A. Hendrickson*, *D. S. Wood* and *D. S. Clark*,
California Institute of Technology

A Study of the Role of Carbon in Temper Embrittlement
By *E. B. Mikus*, General Motors Corp., and *C. A. Siebert*, University of Michigan

Brittle-to-Ductile Transition Temperatures of Binary Chromium-Base Alloys
By *E. P. Abrahamson II* and *N. J. Grant*, Massachusetts Institute of Technology

2:00 P.M. Sherman Hotel

Panel Discussion; Group 3; Metal Fabrication

Selection of Sheet Steel for Formability

Moderator: *Ralph W. E. Leiter*,
The Budd Co.

Panel Members:
Gerald Murray, Pressed Steel Co., Ltd. (England)
Louis McQueen, Jones & Laughlin Steel Corp.

2:00 P.M. Sherman Hotel

Panel Discussion; Group 5; Welding & Joining

Stress Relieving & Preheating

Moderator: *Leon C. Bibber*, U.S. Steel Corp.

Panel Members:
Charles G. Y. Keel, Swiss Acetylene Society (Switzerland)
Perry Arnold, Chicago Bridge & Iron Co.
R. M. Gooderham,
Canadian Welding Bureau
O. R. Carpenter, Babcock & Wilcox
Norman Block, Foster Wheeler Corp.
J. L. Zeyen, Oerlikon Buhrle and Co. (Switzerland)

2:00 P.M. Morrison Hotel

Research Summaries on Science of Metal Hardening

Solute Strengthening in 80 Ni-20 Cr Alloys
By *R. W. Guard*, General Electric Co.

Substitutional Solution Hardening in Copper Alloys
By *Carl Wiseman*, University of California

Quench Hardening in Pure Gold
By *J. W. Kauffman* and *M. Meshii*, Northwestern University

Grain Boundary Sliding in Copper Bi-Crystals
By *J. Intrater* and *E. S. Machlin*, Columbia University

Effect of Carbide Dispersion on the Strength of Tempered Martensite
By *A. M. Turkalo* and *J. R. Low, Jr.*, General Electric Co.

Dispersion Hardening by Spherical Particles
By *H. R. Peiffer, R. H. Read* and *A. J. Shaler*, Pennsylvania State University

Detection of Dislocation Tilts and Strains by X-Rays
By *Larry Kaufman* and *S. A. Kulin*, Massachusetts Institute of Technology

2:00 P.M. Morrison Hotel

Session on Nuclear Metals

Effect of Heat Treatment on Hardness and Microstructure of U-Ti Alloys
By *D. L. Douglass* and *L. L. Marsh, Jr.*, Battelle Memorial Institute

Preferred Orientation in Rolled Uranium
By *M. H. Mueller* and *H. W. Knott*, Argonne National Laboratory; *W. P. Chernock*, Combustion Engineering, Inc., and *P. A. Beck*, University of Illinois

Transformation Kinetics of U-Zr Alloys Containing 50 and 60% U
By *J. J. Kearns*, Westinghouse Electric Corp.

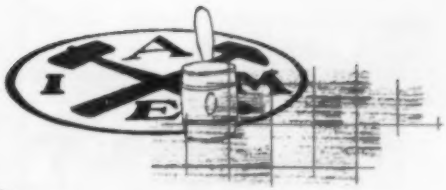
Epsilon Phase in U-Si Alloy
By *S. Isserow*, Nuclear Metals, Inc.

Irradiation Stability of Lean U-Zr Alloys
By *A. H. Willis*, General Electric Co.

Metallography of Irradiated Uranium-Preparation; Cathodic Vacuum Etching; Replication
By *T. K. Bierlein, J. R. Morgan* and *G. R. Mallett*, General Electricc Co.

Corrosion Mechanism of Uranium-Base Alloys in High-Temperature Water
By *M. W. Burkart* and *B. Lustman*, Westinghouse Electric Corp.

A Mechanism by Which Zr and Ti Inhibit Corrosion and Mass Transfer of Steels by Liquid Heavy Metals
By *O. F. Kammerer, J. R. Weeks, J. Sadofsky, W. E. Miller* and *D. H. Gurinsky*, Brookhaven National Laboratory



2:00 P.M. Morrison Hotel

Symposium on Titanium Manufacture and Use

Moderator: *N. E. Promisel*, U.S. Navy, Bureau of Aeronautics

Introduction
By *L. S. Busch*, Mallory-Sharon Titanium Corp.

Airframe Uses

Engine Uses

General Uses

2:00 P.M. Morrison Hotel

Session on Continuous Steelmaking

Moderator: *K. L. Fetters*, Youngstown Sheet & Tube Co.
Panel Leader: *J. F. Elliott*, Massachusetts Institute of Technology

6:30 P.M. Morrison Hotel

Cocktail Party and Dinner

Speaker: *John A. Wilson*, Oriental Institute, University of Chicago

7:00 P.M. Morrison Hotel

Social Hour and Annual Banquet
Presentation of Honor Awards

Wednesday Morning, Nov. 6

7:30 A.M. Palmer House

Chapter Chairmen's Breakfast

8:00 A.M. Palmer House

Annual Meeting of the American Society of Metals

9:00 A.M. Palmer House

Welding of Stainless Steel

(Arranged by A.E.C.'s Internal Group on Welding)

Studies on the Welding of Type 347 Stainless Steel
Reported by *V. N. Krivobok*, International Nickel Co.

9:00 A.M. Morrison Hotel

International Participation Conference

Advantages and Limitations of Nondestructive Tests

a. Characteristics Which Can Be Evaluated
b. Reliability of Test Data
c. Speed of Test Data Collection
d. Cost of Equipment
e. Availability of Equipment

Keynote Speakers:
H. Krainer, Forschungszentrale, Gebr. Bohler & Co. (Austria)
D. W. Ballard, Sandia Corp.
L. van Ouwerkerk, Roentgen Technische Dienst (Holland)

Invited Discussors:
Prof. Hiroshi Kihara, Tokyo University (Japan)
Al Cota, A. O. Smith Corp.

9:00 A.M. Morrison Hotel

Session on Titanium

Analysis of Titanium Alloys by the Vacuum Fusion Method
By *H. Littman, R. P. Barber* and *H. P. Munger*, Syracuse University

Electrical Resistivity Anomalies in Titanium-Oxygen Alloys
By *R. J. Wasilewski*, E. I. du Pont de Nemours and Co.

Interaction of Oxygen With Dislocations in Alpha-Titanium and Its Effect on the Ductile-to-Brittle Transition
By *Devendra Gupta*, New York University and *Sheldon Weinig*, Materials Research Corp.

Effect of Alpha-Beta Ratio on the Heat Treated Properties of Titanium Alloys
By *R. J. Quigg, E. L. Harmon, Jr.* and *A. R. Troiano*, Case Inst. of Technology

Grain-Boundary Adsorption of Solutes and Its Effect on the Creep Properties of Alpha Titanium
By *J. Winter*, New York University and *Sheldon Weinig*, Materials Research Corp.

9:00 A.M. Morrison Hotel

Session on Ferrous Metallurgy

Distribution of Boron in Gamma Iron Grains
By *R. M. Goldhoff*, General Electric Co., and *J. W. Spretnak*, Ohio State University

Some Observations in 885° F. Embrittlement
By *G. F. Tisinai* and *C. H. Samans*, Standard Oil Co. (Indiana)

Studies on the Behavior of Oxygen in Cast Iron
By *Gustaf Ostberg*, Falu Kopparverk (Sweden)

Hot-Pressure Bonding of Iron to Aluminum
By *A. Bartoszak, J. Bedell* and *S. Storchheim*, The Glenn L. Martin Co.

SLA **9:30 A.M. Armour Research Foundation**

(Attendance limited to members of S.L.A.)

Recent Developments in Nonferrous Metals
By *David W. Levinson*, Armour Research Foundation

The Report and Document Library at Armour Research Foundation
By *Mary Patricia Murray*, Armour Research Foundation

Design of a Punched Card System as an Example of Literature Research at Armour Research Foundation
By *Ann P. Wennerberg*, Armour Research Foundation

9:00 A.M. Morrison Hotel

Symposium on Uranium and Uranium Dioxide

Development of Casting Techniques for Uranium and Uranium Alloys
By *G. E. Jaynes, D. T. Doll* and *J. M. Taub*, Los Alamos Scientific Laboratory

Uranium Ingot Production at Atomic Energy Commission Feed Materials Production Centers
By *B. J. Buntz*, Mallinckrodt Chemical Works

Induction Melting of Uranium-Base Alloys
By *N. J. Carson*, Argonne National Lab.

Melting and Casting of U-Zr-Nb Alloys
By *N. J. Carson* and *J. E. Baird*, Argonne National Laboratory

Centrifugal Casting of U-Zr Alloy Rods
By *A. B. Shuck*, Argonne National Lab.

Injection Casting of Uranium-Fission Alloy Pins
By *F. L. Yaggee, J. E. Ayer* and *H. F. Jelinek*, Argonne National Laboratory

Arc Melting of Uranium-Rich Alloys
By *W. H. Britton* and *W. V. Haynes*, Westinghouse Electric Corp.

Press Forging of Ingot Uranium
By *J. A. Fellows* and *H. J. Schaffer*, Mallinckrodt Chemical Works

Rolling of Uranium
By *G. S. Hanks, J. M. Taub* and *D. T. Doll*, Los Alamos Scientific Laboratory

Elevated-Temperature Characteristics of Internally Oxidized Titanium-Cerium Alloys
By *R. H. Hiltz, Jr.* and *N. J. Grant*, Massachusetts Institute of Technology

9:00 A.M. Morrison Hotel

Session on Diffusion

Diffusion of the Elements of the I-B and II-B Sub-Groups in Silver
By *A. Sawatzky*, Franklin Institute, and *F. E. Jaumot, Jr.*, General Motors Corp.

Diffusion of Mg, Si, and Mo in Nickel
By *R. A. Swalin* and *R. Olsen*, University of Minnesota, and *Alan Martin*, Vanadium Corp. of America

Molecular Diffusion and Interphase Transfer Between Solid Copper and Molten Lead
By *J. W. Gorman*, Standard Oil Co. (Indiana) and *G. W. Preckshot*, University of Minnesota

Approximate Method for Calculating Concentration-Dependent Diffusion Coefficients
By *A. G. Guy* and *M. Golomb*, Purdue University,
and *A. S. Yue*, Dow Chemical Co.

9:00 A.M. Palmer House

Campbell Memorial Lecture

Modern Concepts of Flow and Fracture
By *Earl R. Parker*, University of California

12:00 M. Palmer House

University Alumni Luncheons

Wednesday Afternoon, Nov. 6

1:30 P.M. Morrison Hotel

International Participation Conference

Advantages and Limitations of Various Nondestructive Tests

(Continued From Morning)

1:30 P.M. Armour Research Foundation

Inspection of Library and Research Facilities

2:00 P.M. Palmer House

Session on Stainless Steel

Effect of Microstructure and Heat Treatment on Mechanical Properties of Type 431 Stainless Steel
By *G. E. Dieter,* E.I. du Pont de Nemours & Co.

Effect of Aging Cycle on the Properties of an Iron-Base Alloy Hardened With Titanium
By *T. W. Eichelberger,* Westinghouse Electric Corp.

Influence of Nickel on Intergranular Corrosion of 18% Chromium Steels
By *J. R. Upp,* Wright Air Development Center, *F. H. Beck* and *M. G. Fontana,* Ohio State University

Phase Relationships in Austenitic Cr-Mn-C-N Stainless Steels
By *C. M. Hsiao* and *E. J. Dulis,* Crucible Steel Co. of America

Carbide Precipitation and Brittleness in Austenitic Stainless Steel
By *A. Kramer* and *W. M. Baldwin, Jr.,* Case Institute of Technology

2:00 P.M. Palmer House

Welding in Nuclear Power Generators

(Arranged by A.E.C.'s Internal Group on Welding)

Welding of Stainless Steels Which Contain More Than 1% Boron
By *R. A. Noland, C. C. Stone,* Argonne National Laboratory, and *Kenneth Koopman,* Knolls Atomic Power Laboratory

Joining of Stainless Steel to Zircaloy 2 and Zircaloy 3
By *Kenneth Koopman,* Knolls Atomic Power Laboratory

Welding of Uranium
By *R. A. Noland* and *C. C. Stone,* Argonne National Laboratory

2:00 P.M. Sherman Hotel

Panel Discussion; Group 2; Nonferrous Metals

Continuous Casting

Moderator: *Carl E. Swartz,* Consultant, Hinsdale, Ill.

Panel Members:

Hans Wieland, Wieland Werke A. G. (Germany)
J. S. Smart, Jr., American Smelting & Refining Co.
Gerhard Ansel, Dow Chemical Co.
Paul Brenner, Vereinigte Aluminium Werke (Germany)
W. T. Ennor, Aluminum Co. of America
Gerd Beckmann, Lobeck Casting Processes (Germany)
J. L. Hunter, Hunter Engineering Co.
Noman P. Goss, Consultant, Cleveland Ohio

2:00 P.M. Sherman Hotel

Panel Discussion; Group 3; Metal Fabrication

Machining of Steel

Moderator: *H. N. Bogart,* Ford Motor Co.

(a) Approach to the Problem of Machinability
By *M. E. Merchant,* Cincinnati Milling Machine Co.

(b) Microstructure as Related to Machinability of Common Constructural Steels
By *Arthur H. Smith,* Cadillac Motor Division, General Motors Corp.

(c) Effect of Composition of Constructional Steel on Machinability
By *L. W. Derry,* Battersea Polytechnic Institute (England), and
G. R. Caskey, Bliss & Laughlin, Inc.

2:00 P.M. Morrison Hotel

Symposium on Uranium and Uranium Dioxide

Extrusion of Uranium
By *P. Loewenstein*, Nuclear Metals, Inc.

Cold Working of Uranium
By *J. M. Taub, D. T. Doll* and *G. S. Hanks*, Los Alamos Scientific Laboratory

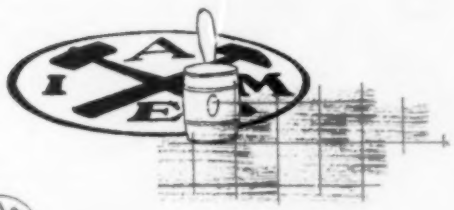
Fusion Welding of Uranium
By *E. L. Brundige, D. T. Doll, G. S. Hanks* and *J. M. Taub*,
Los Alamos Scientific Laboratory

Powder Metallurgy of Uranium and Uranium Alloys
By *J. L. Zambrow*, Sylvania-Corning Nuclear Corp.

Various Methods of Preparing Uranium Dioxide for Fuel Element Use
By *G. W. Thompkin, D. E. Rhodes* and *C. M. Henderson*,
Mallinckrodt Chemical Works

Fabrication of Bulk Form Uranium Dioxide for Use as Nuclear Reactor Fuel
By *J. Glatter*, Westinghouse Electric Corp.

Fabrication of High-Density Uranium Dioxide Fuel Components for the First Pressurized Water Reactor Core
By *T. J. Burke, J. Glatter, H. R. Hoge* and *B. E. Schaner*, Westinghouse Electric Corp.



2:00 P.M. Morrison Hotel

Relation of Structure and High-Temperature Properties

Variables Affecting Young's Modulus of Magnesium Alloys at Elevated Temperatures
By *R. W. Fenn, Jr.*, Dow Chemical Co.

Structure and Creep Resistance of Magnesium Alloys
By *E. F. Emley*, Magnesium Elektron Ltd. (England)

Recovery and Recrystallization in the Creep-Rupture Behavior of 2S Aluminum
By *M. B. Happ* and *N. J. Grant*,
Massachusetts Institute of Technology

Structural Modifications of Steel During High-Temperature Deformation
By *C. Crussard* and *R. Tamhankar*,
Institut de Recherches de la Siderurgie (France)

Role of Subgrains in Creep
By *J. E. Dorn* and *L. Shephard*, University of California

Role of Grain Boundaries in Creep
By *E. R. Parker*, University of California

2:00 P.M. Morrison Hotel

Session on Transformations

Micrographic Investigation of Precipitation in Pb-Sn Alloys
By *D. Turnbull* and *H. N. Treaftis*
General Electric Co.

Mechanism of Precipitation in an Alloy of Copper With 2.5% Iron
By *J. B. Newkirk*, General Electric Co.

High-Temperature Development of Minor Phases in a Nickel-Base Alloy
By *W. C. Bigelow, J. A. Amy* and *L. O. Brockway*, University of Michigan

X-Ray Investigation of Recrystallized Aluminum
By *S. Weissman*, Rutgers University

Transformation Kinetics and Mechanical Properties of Zr-Mo Alloys
By *R. F. Domagala, D. W. Levinson* and *D. J. McPherson*,
Armour Research Foundation

Textures of Cold-Rolled and Recrystallized Crystals of Silicon-Iron
By *J. L. Walter* and *W. R. Hibbard, Jr.*,
General Electric Co.

"Nuclei" for Secondary Recrystallization in Silicon-Iron
By *C. G. Dunn*, General Electric Co., and *P. K. Koh*, Allegheny Ludlum Steel Corp.

Intermetallic Compounds in Titanium Hardened Alloys
By *H. J. Beattie, Jr.*, and *W. C. Hagel*,
General Electric Co.

2:00 P.M. Morrison Hotel

Session on General Metallurgy

Precipitation and Magnetic Annealing in a Cu-Co Alloy
By *J. J. Becker*, General Electric Co.

Processing and Properties of Co-Pt Permanent Magnet Alloys
By *D. L. Martin*, General Electric Co.

Elimination of Magnetic Effects in Be-Cu
By *Harold Bernstein*, U.S. Naval Gun Factory

Nitrides of Silicon
By *W. D. Forgeng*, Electro Metallurgical Co., and
B. F. Decker, General Electric Co.

CsCl-Type Ordered Structures in Binary Alloys of Transition Elements
By *T. V. Philip*, Crucible Steel Co. of America and *P. A. Beck*, University of Illinois

Atomic Size Effects in Cr_3O-Type Structures
By *M. V. Nevitt*,
Argonne National Laboratory

Internal Friction in Columbium
By *R. W. Powers* and *Margaret V. Doyle*,
General Electric Co.

Some Features of Zone Melting
By *J. H. Wernick*,
Bell Telephone Laboratories

Thursday Morning, Nov. 7

9:00 A.M. Palmer House

Session on Mechanical Properties

Effects of Temperature and Time on the Tensile Properties of Aluminum Alloys for Airframes
By *R. E. Fortney* and *C. H. Avery*, Northrop Aircraft

Apparatus for Determining the Hardness of Metals up to 3000° F.
By *M. Semchyshen* and *C. S. Torgerson*, Climax Molybdenum Co. of Michigan

Mechanical Properties of Forged Chromium
By *S. A. Spachner* and *W. Rostoker*, Armour Research Foundation

Deformation and Fracture of Li-Mg Solid Solutions
By *F. E. Hauser, P. R. Landon and John E. Dorn*, University of California

9:00 A.M. Palmer House

Thermal Cycling of Uranium

Effects of Fabrication and Heat Treatment Variables
By *S. T. Zegler, R. M. Mayfield* and *M. H. Mueller*, Argonne National Laboratory

Growth of Uranium Upon Thermal Cycling
By *J. E. Burke* and *A. M. Turkalo*, General Electric Co.

Microstructural Changes of Uranium
By *L. T. Lloyd* and *R. M. Mayfield*, Argonne National Laboratory

Effects of Cycling Variables Upon Growth of Rolled Uranium
By *R. M. Mayfield*, Argonne National Laboratory

Some Properties of Uranium Alloys Low in Titanium
By *Daniel J. Murphy*, Univ. of Arizona

9:00 A.M. Palmer House

Advanced Metallographic Techniques

(Arranged by A.E.C.'s Internal Group on Metallography)

Historical Background
By *Cyril Stanley Smith*, University of Chicago

Early Work With Ultra-Violet
By *Francis F. Lucas*, Bell Telephone Laboratories (Retired)

Metallographic Grinding and Polishing
By *L. E. Samuels*, Defense Standards Laboratories (Australia)

Revelation of Structures Through Surface Treatment
By *E. C. W. Perryman*, Aluminium Laboratories, Ltd. (Canada)

Incident Light Microscopy
By *George L. Kehl*, Columbia University

Microradiography, Auto-Radiography and X-Ray Microscopy
By *Sterling Newberry*, General Electric Co.

Electron Microscopy
By *W. C. Bigelow*, University of Michigan

Summary and Critique
Cyril Stanley Smith, University of Chicago

9:00 A.M. Sherman Hotel

Panel Discussion; Group 1; Steelmaking & Refining

Topic: Iron

Moderator: *Robert L. Stephenson*, United States Steel Corp.

(a) Present Technology of Ironmaking
By *Walther A. Guldner*, High Authority, European Community (Luxembourg), and *J. D. Saussaman*, Kaiser Steel Co.

(b) Developments in Ironmaking
By *E. Bonnaure* (Belgium), and *Michael O. Holowaty*, Inland Steel Co.

(c) Direct Reduction of Iron
By *P. E. Cavanagh*, Ontario Research Foundation (Canada), and *Bruce Old*, Arthur D. Little, Inc.

9:00 A.M. Sherman Hotel

Panel Discussion; Group 2; Nonferrous Metals

Practical Aspects of Metal Degassing

Moderator: *Albert J. Phillips*, American Smelting & Refining Co.

Panel Members:
Ernest Scheuer, International Alloys Co., Ltd. (England)
L. W. Eastwood, Kaiser Aluminum & Chemical Corp.
J. H. Jackson, Battelle Memorial Institute
George Timmons, Climax Molybdenum Co. of Michigan
Charles E. Nelson, Dow Chemical Co.
R. A. Kozlik, International Nickel Co.

9:00 A.M. Sherman Hotel

Panel Discussion; Group 8; Education and Research

Metallurgical Education

Moderator: *Robert F. Mehl,* Carnegie Institute of Technology

(a) Physical Metallurgy
By *Thomas A. Read,* University of Illinois, and *T. Mishima,* University of Tokyo (Japan)

(b) Process Metallurgy
By *W. O. Philbrook,* Carnegie Institute of Technology, and *G. Letendre,* Laval University (Canada)

(c) Graduate Work in Metallurgy
By *Earl R. Parker,* University of California

(d) Industrial Training
By *Harry Smith,* U.S. Steel Corp.

9:00 A.M. Morrison Hotel

Session on Deformation and Related Properties

Role of Polygonization in Creep
By *R. W. Guard,* General Electric Co.

Comparison of the Creep-Rupture Properties of Nickel in Air and Vacuum
By *P. Shahinian* and *M. R. Achter,* U.S. Naval Research Laboratory

Deformation of Rhenium
By *A. T. Churchman,* Associated Electrical Industries, Ltd., London

Internal Friction in Aluminum at Low Temperature
By *A. J. Filmer, G. J. Hutton* and *T. S.* Hutchison, Royal Military College of Canada

Deformation of Aluminum Single Crystals at -77° C.
By *A. Kelly* and *S. Sato,* Northwestern University

Resistivity Recovery in Cold Worked Aluminum
By *H. R. Peiffer* and *I. R. Kramer,* Rias, Inc.

Mechanical Behavior of Microcrystals
By *W. W. Webb* and *W. D. Forgeng,* Electro Metallurgical Co., Div. of Union Carbide Corp.

Motion of Dislocations Opposed by a Frictional Force
By *H. R. Peiffer,* Rias, Inc.

Viscous Dislocation Motion in LiF
By *J. J. Gilman* and *W. G. Johnston,* General Electric Co.

Effect of Heat Treatment on the Coercive Force of Aluminum-Iron Alloys in the Ordering Region
By *K. Foster* and *D. Pavlovic,* Westinghouse Electric Corp.

9:00 A.M. Morrison Hotel

Symposium on Powder Metallurgy

Sintering of Aluminum Oxides
By *George Kuczynski,* University of Notre Dame

Rate of Infiltration of Metals
By *K. A. Semlak* and *F. N. Rhines,* Carnegie Institute of Technology

Effect of Specific Surface Area of Iron Powder on the Hot-Coined Specimens
By *D. P. Ferriss* and *J. G. Byrne,* Stevens Institute of Technology

High-Temperature Properties of Nickel and Cobalt Alloy Powder Extrusions Containing Nonmetallic Dispersions
By *C. G. Goetzel* and *Eric Gregory,* Sintercast Corp. of America

Hot Coining Cobalt-Base Metal Powders With Minor Additives.
By *D. P. Ferriss, E. B. Wilson* and *G. J. Comstock,* Stevens Institute of Technology

9:00 A.M. Morrison Hotel

Educational Program

Nondestructive Testing Techniques (Part I)

Orientation
By *D. T. O'Connor,* Chairman SNT Educational Committee

Magnetic Particle Inspection
By *W. E. Thomas,* Magnaflux Corp.

Principles of Radiography
By *W. D. Kiehle,* Eastman Kodak Co.

Industrial Fluoroscopy
By *W. R. Hampe,* Westinghouse Electric Corp.

Radiographic Film Interpretation
By *A. L. Pace,* General Electric Co.

Penetrant Testing
By *T. De Forest,* Magnaflux Corp.

9:30 A.M. International Harvester Co.'s Central School

Progress in Ferrous Metallurgy

Advances in Ferrous Research
By *R. H. Aborn,* U.S. Steel Corp.

Contribution of Physics to Metallurgy
By *David S. Lieberman,* University of Illinois

High-Temperature Alloys
By *M. C. Metzger,* Universal-Cyclops Steel Corp.

Thursday Afternoon, Nov. 7

SLA

1:30 P.M. International Harvester Co.

Tour of Manufacturing Research Dept.

(Limited to S.L.A. Members)

Philosophy of Manufacturing Research
By *A. S. Jameson,*
International Harvester Co.

SNT

1:30 P.M. Morrison Hotel

Educational Program

Nondestructive Testing Techniques (Part II)

Eddy Current Testing in Theory
By *G. O. McClurg,* Magnaflux Corp.

Eddy Current Testing in Practice
By *J. Allen,* Oak Ridge National Laboratory, Union Carbide Nuclear Co.

Ultrasonic Testing Pulse Method
By *J. C. Smack,* Curtiss-Wright Corp.

Ultrasonic Testing Resonant Method
By *P. K. Bloch,* Branson Instrument Co.

AS M

3:00 P.M. Palmer House

Session on Physical Metallurgy

Grain Boundary Movement in Bicrystalline Aluminum
By *R. B. Pond* and *E. Harrison,*
Johns Hopkins University

Growth of Cadmium From Vapor
By *J. E. McNutt,* E. I. duPont de Nemours & Co., and *R. F. Mehl,* Carnegie Institute of Technology

The Self-Diffusion of Nickel at Grain Boundaries
By *W. R. Upthegrove,* University of Oklahoma, and *M. J. Sinnott,* University of Michigan

Effects of Oxide Recrystallization on the Oxidation Kinetics of a 62-38 Cu-Ni Alloy
By *J. A. Sartell, S. Bendel, T. L. Johnston* and *C. H. Li,* Minneapolis-Honeywell Research Center

Temperature Stresses in the Two-Phase Alloy, WC-Co
By *J. Gurland,* Brown University

AS M

2:00 P.M. Palmer House

Metallography of Nuclear Materials

(Arranged by A.E.C.'s Internal Group on Metallography)

Metallography of Uranium
By *R. F. Dickerson,*
Battelle Memorial Institute

Metallographic Identification of Inclusions in Uranium
By *G. L. Kehl,* Columbia University, *Eric Mendel* and *Emilio Jaraiz F.,* Columbia University, and *Melvin H. Mueller,* Argonne National Laboratory

Preparation and Metallography of Uranium Carbides
By *R. J. Gray, C. K. H. DuBose,* and *W. C. Thurber*

Transformation Structures in Uranium-Columbium Base Alloys
By *F. C. Holtz* and *R. J. Van Thyne,*
Armour Research Foundation

A Physical Metallurgical Study of Thorium-Rich Thorium-Uranium Alloys
By *G. G. Bentle,* Atomics International

An Adventure in Metallurgy—Micro-Deformation and Fracture in Uranium
By *T. K. Bierlein* and *R. E. Hueschen,*
General Electric Co.,
Hanford Atomic Products operation

WRC

2:00 P.M. Sherman Hotel

Panel Discussion; Group 1; Steelmaking & Refining

Topic: Steelmaking

Moderator: *Howard Turner,*
Jones & Laughlin Steel Corp.

(a) Oxygen in Steelmaking
By *Harold Emerick,*
Jones & Laughlin Steel Corp.

(b) Vacuum Melting
By *Otto Winkler,* Geratebau-Anstalt Balzers (Liechtenstein), and *James H. Moore,* Metal Hydrides, Inc.

(c) Vacuum Degassing
By *Fritz Harders,* Dortmund-Horder Huttenunion A.G. (Germany), and *E. C. Bain,* U.S. Steel Corp.

2:00 P.M. Sherman Hotel

Panel Discussion; Group 6; Inspection & Testing

Testing in Product Development

Co-Moderators:
H. N. Bogart, Ford Motor Co., and
G. W. Stickley, Aluminum Co. of Amer.

(a) Large Components
By *Andrew W. Rankin*, General Electric Co., and
Thomas E. Eagan, Cooper-Bessemer Corp.

(b) Medium Size Components
By *L. J. A. Delay*, Sud Aviation (France), and *D. K. Hanink*, Allison Engine Div. General Motors Corp.

(c) Small Components
By *H. Sigwart*, Daimler-Benz A.G. (Germany),
and *W. H. Lehmann*, Chrysler Corp.

2:00 P.M. Sherman Hotel

Panel Discussion; Group 8; Education & Research

Trends in Metallurgical Research

Moderator: *Clyde L. Williams*, Battelle Memorial Institute

(a) Industrial Research
By *Ivor Jenkins*, General Electric Co., Ltd. (England), and
E. C. Bain, U.S. Steel Corp.

(b) Government Research and Government-Sponsored Research
By *Julius Harwood*, Office of Naval Research, and *N. P. Allen*, National Physical Laboratory (England)

(c) Institutes and Research Consultant Groups
By *Bruce Old*, Arthur D. Little, Inc., and *E. A. G. Liddiard*, Fulmer Research Institute (England)

(d) University Research
By *R. F. Mehl*, Carnegie Institute of Technology, and *Hans Nowotny*, Technischen Hochschule Wien (Austria)

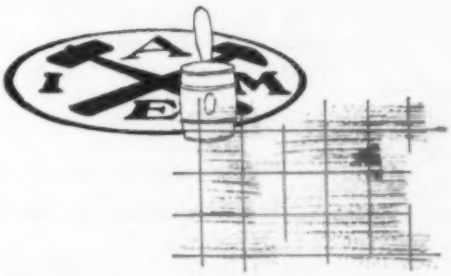
2:00 P.M. Palmer House

Joint Session With ⊜ on Powder Metallurgy

Current Advances in the Science of Powder Metallurgy
By *Joseph E. Burke* and *Harold H. Hirsch*, General Electric Co.

Iron Powder From the "H-Iron" Process
By *J. F. Kuzmick*, Alan Wood Steel Co.

Metal Powder to Solid Strip—Status of Commercial Production
By *Wm. N. Hayden*, Hayden Metals, Inc. and *John D. Shaw* and *Walter V. Knopp*, S-K-C Research Associates



2:30 P.M. Morrison Hotel

Equilibrium Studies

Delta Phase Field of the U-Zr Diagram
By *J. F. Duffey* and *C. A. Bruch*, General Electric Co.

Constitution of the Uranium-Rich U-Cb and U-Cb-Zr Systems
By *A. E. Dwight* and *M. H. Mueller*, Argonne National Laboratory

Nature of the Ni-Cr System
By *R. O. Williams*, Cincinnati Milling Machine Co.

Activity Measurements in the Fe-Cr System
By *C. L. McCabe*, *R. G. Hudson* and *H. W. Paxton*,
Carnegie Institute of Technology

A Thermodynamic Study of Liquid Pb-Zn Solutions
By *F. D. Rosenthal* and *G. J. Mills*, California Institute of Technology, and *F. J. Dunkerley*, Rolle Mfg. Co.

Solid Solubility of Uranium in Thorium and the Allotropic Transformation of U-Th Alloys
By *W. B. Wilson*, *A. E. Austin* and *C. M. Schwartz*, Battelle Memorial Institute

Liquid Miscibility Gap in the Quaternary System Fe-Cu-S-C at 1450° C.
By *D. L. Douglass*, Ohio State University

Uranium-Columbium Alloy Diagram
By *B. A. Rogers*, *D. F. Atkins*, *E. J. Manthos* and *M. E. Kirkpatrick*, Iowa State College

Thursday Afternoon, Nov. 7

(Continued)

2:00 P.M. Morrison Hotel

Research Summaries

(Transformations and Alloys)

Growth of Pearlite
By *L. S. Darken, R. M. Fisher* and *J. M. Galligan,* United States Steel Corp.

Effect of Applied Tensile Stress on Phase Transformations in Steel
By *L. F. Porter,* U. S. Steel Corp., and *P. C. Rosenthal,* University of Wisconsin

Nature and Kinetics of Precipitation in a 16% V, 2.5% Al Titanium Alloy
By *E. L. Harmon,* Electro Metallurgical Co., Div. of Union Carbide Corp., and *A. R. Troiano,* Case Institute of Technology

Diffusion of Heat and Mass in Growth of Precipitates From Supersaturated Solutions
By *C. M. Adams, Jr.,* Massachusetts Institute of Technology

Abnormal Grain Growth in High-Purity, Extruded Magnesium
By *F. D. Rosenthal* and *G. J. Mills,* Jet Propulsion Laboratory, California Institute of Technology

A Contribution to the Phase Diagram of Silver-Copper-Cadmium
By *K. M. Weigert,* Curtiss-Wright Corp.

Heat Treatment, Transformation Reactions, and Mechanical Properties of Some High-Strength Zirconium-Base Alloys
By *H. A. Robinson, J. F. Doig, M. W. Mote* and *P. D. Frost,*
Battelle Memorial Institute

Solid Solubility of Carbon in Copper-Nickel Alloys
By *M. E. Nicholson,* Univ. of Minnesota

Solubility of Hydrogen in the 50 Weight Per Cent Uranium-Zirconium Alloy
By *E. A. Gulbransen, K. F. Andrew* and *R. J. Ruka,* Westinghouse Electric Corp.

Thermal Fatigue of Ductile Materials—I. Effect of Test Conditions on the Thermal Fatigue Life of S-816 and Inconel 550
By *F. J. Clauss,* Lewis Flight Propulsion Laboratory, and *J. W. Freeman,*
University of Michigan

Thermal Fatigue of Ductile Materials—II. Effect of Cyclic Thermal Stressing on the Stress-Rupture Life and Ductility of S-816 and Inconel 550
By *F. J. Clauss,* Lewis Flight Propulsion Laboratory, and *J. W. Freeman,*
University of Michigan

Thursday Evening

6:30 P.M. Palmer House

Annual Banquet and Entertainment

6:00 P.M. Younker's Restaurant

Social Hour and Dinner

Speaker: *Herman Henkle,*
John Crerar Library

Friday Morning, Nov. 8

9:00 A.M. Sherman Hotel

Panel Discussion; Group 1; Steelmaking & Refining

Solidification of Steel

Moderator: *Charles W. Sherman,* Jones & Laughlin Steel Corp.

(a) Ingot Technology
By *Bernhard Matuschka,* Schoeller-Bleckmann Steel Works (Austria), and *G. A. Dornin, Jr.,* Consulting Engineer

(b) Controlled Nucleation
By *J. L. Walker,* General Electric Co.

(c) Continuous Casting
By *Karl G. Speith,* Mannesmann-Huttenwerke A.G. (Germany), and *Robert Clark,* Atlas Steels Ltd., Canada

9:00 A.M. Sherman Hotel

Panel Discussion; Group 6; Inspection & Testing

Testing for Quality Control After Product Development

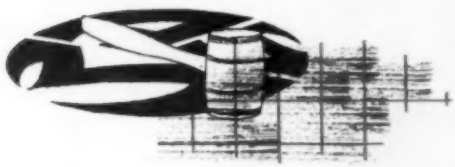
Co-Moderators:
R. F. Thomson, General Motors Corp., and *T. E. Piper,* General Dynamics Corp.

(a) Wrought Semi-Finished Product
By *R. S. Pratt,* Bridgeport Brass Co., *J. W. Hood,* Aluminum Co. of America, and *W. H. Mayo,* U.S. Steel Corp.

(b) Cast Semi-Finished Product
By *A. Karam,* General Motors Corp.

(c) Automotive Components
By *W. H. Grundeman,* Chrysler Corp.

(d) Aircraft Components
By *R. A. Day,* Blackburn & General Aircraft, Ltd. (England), and *B. R. Swarts,* General Dynamics Corp.



9:30 A.M. Morrison Hotel

International Participation Conference

Development of Standardized Techniques in Nondestructive Testing

Keynote Speakers:
Richard Seifert, R. Seifert & Co.
Prof. Oscar Masi, Fiat-Division Siderurgique (Italy)
R. B. Oliver, Oak Ridge National Laboratory

Invited Discussors:
Werner Felix, Sulzer Bros. Ltd. (Switzerland)
Donald C. Erdman, Metrol, Inc.

9:30 A.M. International Harvester Co. (Central School)

International Aspects of Metallurgical Literature Classification

Special Library and Information Services in England
By *Anthony Post,*
Iron & Steel Institute (London)

Activities and Functions of French Documentation Center
By *Marc Allard* and *Max Dupont,* Centre de Documentation Siderurgique (France)

Bibliographic Services in the Aluminum Industry
By *Ernst A. Bloch,*
Aluminium-Industrie A.G., Switzerland.

Importance of Documentation
By *Frank T. Sisco,*
Engineering Foundation

Friday Noon, Nov. 8

12:00 M. Saddle & Sirloin Club, Chicago Stock Yards

Distinguished Service Luncheon

For 25-Year ASM Members and Invited Students

Friday Afternoon

2:00 P.M. Morrison Hotel

International Participation Conference

Development of Standardized Techniques in Nondestructive Testing

(Continued from Morning)

2:00 P.M.

Visits to Selected Special Libraries

2:45 P.M. Enrico Fermi Institute, University of Chicago

15th Anniversary of First Sustained Chain Reaction

Presentation of Commemorative Plaque

Friday Evening

6:00 P.M. International Amphitheater

39th Annual Metal Exposition Closes

7:00 P.M. Palmer House

Farewell Banquet

Exhibitor Listing

A

A. I. T. Diamond Tool Co., Inc. 1714
Abrasive wheels, plunge grinding.

Aaron Machinery Co., Inc. 1505
Grinders, boring, drilling and milling machines.

Abrading Systems Co. 1384
Automatic flat lapping machines.

Acheson Colloids Co. 112
Lubricants, solid and liquid; glass dispersions.

Acme Steel Co. 441
Metal stitchers and steel strapping.

Ajax Electric Co., Inc. 1406
Salt bath furnace equipment.

Ajax Electrothermic Corp. 1406
High-frequency induction furnaces.

Ajax Engineering Corp. 1406
Low-frequency induction melting furnaces.

Ajusto Equipment Co. 1498
Workman's chairs and stools.

Alan and Associates, Mark 1388
See Cooke, Troughton & Sims, Ltd.

Al-Fin Div., Fairchild Engine & Airplane Corp. 915
Cast aluminum and magnesium bonded bimetallic components.

Allegheny Ludlum Steel Corp. 648
Heat and corrosion resistant alloys, tool and die steels and cemented carbides.

Allis-Chalmers Mfg. Co., Buda Division 935
Fork lift truck.

Allison Div., American Chain & Cable Co., Inc. 1849
Abrasive cutting wheels.

Alloy Engineering & Casting Co. 442
Heat and corrosion resistant castings.

Aloris Tool Co., Inc. 1589
Tool posts and holders.

American Brake Shoe Co. 336
See Electro-Alloys Division; also Light Metals Dept.

American Cast Iron Pipe Co. 1376
Centrifugal castings.

American Chain & Cable Co., Inc. 953, 1849
See Allison Div., Campbell Machine Div. and Wilson Mechanical Instrument Div.

American Chemical Paint Co. 201
Metal cleaning and finishing compounds, rust preventives, drawing compounds.

American Cyanamid Co. 1815
Heat treating compounds and metallurgical additives.

American Cystoscope Makers, Inc. 1764
Borescopes and optical flats.

American Gas Association 718-754
Industrial gas furnaces, ovens and burners.

American Gas Furnace Co. 726
Automatic heat treating equipment.

American Herforder Corp. 1667
See also Metal Removal Co.

American Machine & Metals, Inc. 820
See Riehle Testing Machine Div.

American Machinist 109

American Metal Market Co. 1668
American Metal Market and *Metal Statistics.*

American Optical Co. 1047
Metallographic equipment.

American Positive Grip Vise Corp. 1581
Ampogrip holding fixtures.

American Pullmax Co., Inc. 1065
Universal shearing and forming machines.

American Silver Co., Inc. 815
Very thin, close-tolerance metal strip.

Ampco Metal, Inc. 1768
Cast, rolled and wrought bronzes, particularly aluminum bronze, arc welding electrodes and other products.

Amperex Electronic Corp. 1630
Electronic tubes for industrial applications.

Amplex Div., Chrysler Corp. 1663
Self-lubricating bearings and special parts made by powder metallurgy.

Applied Research Laboratories 1239
Spectrographic equipment.

Arcair Co. 1271
Torches and electrodes for arc gouging and cutting.

Arcweld Mfg. Co. 1019
High-temperature testing equipment, creep testing.

Aro Spot Welder Div. 1692
See Guthery Machine Tool Corp.

Associated Spring Corp. 1535
Springs, wire forms, small stampings.

Atlantic Machine Tool Works 1549
Jig borer.

Atlas Mineral Products Co. 1784
Corrosion resistant cements and plastics.

Atlas Press Co., Clausing Div. 1350
Machine tools, lathes, drill presses, millers and shapers.

Atomic Energy Commission, Industrial Information Branch

Audubon Wire Cloth Corp. 215
Corrosion and heat resistant conveyer belts.

Automation Instruments, Inc. 153

B

Babcock & Wilcox Co., Tubular Products Div. 628
Tubular products and extrusions.

Baird-Atomic, Inc. 265
Spectrometers and accessories, carbon and sulphur analyzers.

Baker & Co., Inc. 119
Electrical contacts and contact material, precious metal parts and cladding, Nitroneal generator.

Balcrank Inc. 1895
Paint pumping equipment.

Baldwin-Lima-Hamilton Corp. 1258
Sr-4 devices and equipment, testing equipment.

Balteau Electric Corp. 1373
Portable industrial X-ray units.

Banner Welder, Inc. 125
Resistance welding equipment.

Barber-Colman Co., Wheelco Instruments Div. 941
Recorders and controllers with combustion safeguards.

Barer Engineering & Machinery Co., Ltd. 502
Lathes, drill presses, shapers and grinders.

Barry Controls, Inc. 1294
Machinery mounts and noise control equipment.

Battelle Memorial Institute 1314
See Cobalt Information Center.

Bausch & Lomb Optical Co. 1054
Metallographic equipment.

Bean & Co., Morris 415
Antioch process aluminum castings, ductile iron castings.

Bede Products Corp. 220
Airless spray coating equipment.

Bedford Gear & Machine Products, Inc. 129
Precision gears and spline shafts, tool and gages.

Bendix Aviation Corp. 1481
See Friez Instrument Div.

Beryllium Corp. 1688
Beryllium-copper alloys and pure beryllium.

Big Joe Mfg. Co. 136
Special die handling trucks, lift trucks.

Binks Mfg. Co. 1629
Paint spraying equipment.

Bjorksten Research Laboratories for Industry, Inc. 1893
Chemical laboratory developments.

Black & Decker Mfg. Co. 241
Drills, grinders, small tools, hand tools, industrial vacuum cleaners.

Black Drill Co., Inc. 419
Drills for hardened steel.

Blakeslee & Co., G. S. 1277
Cleaning equipment.

Bradley Washfountain Co. 1597
Group washing equipment, drinking fountains.

Branson Instruments, Inc. Branson Ultrasonic Corp. 1854
Ultrasonic generators and thickness gages.

Brinkman Instruments, Inc. 835
Dilatometers, balances, microscopes, metallographs.

British Industries Corp. 1679
Die casting machines and Shaw process.

Bruning Co., Inc., Charles 1405
Drafting machines and tables.

Brush Beryllium Co. 148
Beryllium and beryllium alloys.

Buck Mfg. Co. 1389
Magnetic drill presses and clamping equipment.

Buck Tool Co. 1036
Universal chucks, power chucks, boring bars.

Buda Div. 935
See Allis Chalmers Mfg. Co.

Budd Co. 1715
Gamma radiation sources for industrial radiography.

Buehler Ltd. 1235
Equipment for preparation of metallographic specimens, microscopes and metallographs.

C

C. I. T. Corp. 1741
Installment service for buyers and sellers of machinery.

Cam-Lok Div., Empire Products, Inc. 1337
Waterproof connectors and molding kits.

Campbell Machine Div., American Chain & Cable Co. 1849
Wet and dry abrasive cutting machines.

Carlingo Commodities Corp. 1360
Flame hardening equipment, pyrometers.

Carlson, Inc., C. R. 1754
See FAC Division of Overseas Commodex Corp.

Carter Controls, Inc. 1794
Air and hydraulic cylinders, valves and rotary actuators.

Casting Engineers, Inc. Division of Consolidated Foundries & Mfg. Corp. 1746
Precision investment castings.

Center for Documentation and Communication Research, Western Reserve University
Literature searching equipment and techniques.

Chainveyer Corp. 1826
Conveyers and material handling equipment.

Challenge Machinery Co. 1059
Toolroom equipment, floor plates and layout tables.

Chicago Bridge & Iron Co. 1519
Steel tanks for oil, liquid and gas.

Chicago Foundry Co. 1689

Chicago Powdered Metal Products Co. 1883
Powdered metal parts.

Chicago Rivet & Machine Co. 1835
Tubular rivets and automatic rivet setting machines.

Chicago Supply & Tool Co. 1456
Machine tools, band saws, milling machines and shears.

Chilton Co. 456
Iron Age, Automotive Industries.

Chrysler Corp. 1663
See Amplex Div.

Cincinnati Milling Machine Co., Process Machinery Div. 1798
High-frequency induction heating machine, Flamatic hardening machine.

Cincinnati Sub-Zero Products 1583
Production chilling machines, low-temperature testing equipment.

Circo Equipment Co. 1582
Spray washer, vapor degreaser and ultrasonic metal cleaning equipment.

Clark Co., Robert H. 263
Small tools.

Clausing Div. 1350
See Atlas Press Co.

Clementina Ltd. 1695
Blast cleaning equipment.

Cleveland Grinding Machine Sales, Inc. 860
Grinding equipment and accessories.

Cleveland Metal Abrasive Co. 831
Cleaning and peening shot and grit.

Climax Molybdenum Co. 368
Molybdenum as base and alloying element.

Coated Coil Corp. 1357
See Enamelstrip Corp.

Cobalt Information Center, Battelle Memorial Institute 1314
Cobalt samples, information about cobalt.

Cold Metal Products Co. 1127
See Jones & Laughlin Steel Corp., Strip Steel Div.

Collins Microflat Co. 1880
Black granite surface plates.

Commander Mfg. Co. 1035
Multiple drill and tapping heads.

Commercial Shearing & Stamping Co., Inc. 1587
Hydra-jet descalers.

Consolidated Electrodynamics Corp. 1236
Vacuum melting furnaces, gages, valves, pumps and instruments.

Consolidated Foundries & Mfg. Corp. 1746
See Casting Engineers, Inc.

Continental Industrial Engineers, Inc. 738
Heat treating equipment.

Cooke, Troughton & Sims, Ltd. 1388
Metallurgical microscopes.

Cooper Metallurgical Associates 1579
Pure boron, boron alloys and borides.

Copper & Brass Research Assoc. 1670
Copper and copper alloy parts and components, shapes and forms.

Copperweld Steel Co., Steel Div. 526
Standard and leaded alloy and carbon steel, speciality steel.

Crane Packing Co. 1240
Lapping machines and mechanical packing.

Curtiss-Wright Corp., Industrial and Scientific Div. 602
Ultrasonic equipment; forgings, extrusions and castings.

Cushman & Denison Mfg. Co., Inc. 1887
Cado marker.

Cycledynamics, Inc. 1593
Electromagnetic power transmission components.

D

Dake Corp. 960
Arbor, hydraulic shop and guided platen presses.

Daubert Chemical Co. 1664

De Sanno & Son, Inc., A. P. 1220
Abrasive cutoff machines and grinding wheels.

Designers Metal Corp. 1756
Expanded metal and expanded metal products.

Detrex Chemical Industries, Inc. 1316
Cleaning and finishing compounds and equipment.

Detroit Testing Machine Co. 848
Hardness, tensile and ductility testers.

DeVilbiss Co. 1708
Spray painting machines, paint heating equipment.

DeWalt, Inc. 1285
Radial arm metal cutting machinery; dynamic power brakes.

DeZurik Corp. 1792
Eccentric plug valve, on-off and positioning type air operated for automatic control application.

Disston Div., Henry, H. K. Porter Co., Inc. 1863
Metalworking saws.

Diversey Corp. 147
Cleaning and phosphating chemicals.

DoAll Co. 360
Sawing machines, grinders, cutting tools, inspection equipment.

Doehler-Jarvis Div., National Lead Co. 1506
Die castings.

Dow Chemical Co. 1790
Magnesium products, cleaning solvents.

Driver Co., Wilbur B. 1257
Vacuum melted alloys and wire, strip and rod forms.

Drop Forging Assoc. 1491
Drop forgings.

Dry Clime Lamp Corp. 1755
Infrared ovens.

DuBois Co., Inc. 1393
Cleaning and processing compounds.

Dumore Co. 1839
Automatic drill heads and units, grinders, flexible shaft tools.

Du Pont de Nemours & Co., Inc., E. I. 1845
Vapor degreasing, industrial rivets.

E

Easco Products Div., Electro Arc Mfg. Co. 126
Metal disintegrators and conversion units.

Eastman Kodak Co. 1429
Industrial X-ray film.

Eclipse Fuel Engineering Co. 735
Controlled atmospheric heat treating furnaces, gas generators, valves and burners.

Electric Furnace Co. 1135
Industrial heat processing furnaces.

Electro-Alloys Div., American Brake Shoe Co. 336
Heat resisting castings, conveyor belts and furnace parts.

Electro Arc Mfg. Co. 126
See Easco Products Div.

Electro Dynamic Div., General Dynamics Corp. 1642
Variable speed drives, electric motors.

Electromark Corp. 1484
Metal marking process.

Electro Metallurgical Co. 539
Titanium; Cr-Ni-Mn stainless steels.

Elox Corp. of Michigan 1436
Precision electrical discharge machine, electronic grinders.

Empire Products, Inc. 1337
See Cam-Lok Div.

Enamelstrip Corp. 1357
Precoated steel in coils.

Engis Equipment Co. 1644
Precision tooling and measurement instruments.

Etteo Tool & Machine Co., Inc. 1487
Chucks, tapping attachments and machines, indexing fixtures.

Everite Machine Products Co. 1480
Electrochemical grinders.

Exomet, Inc. 1697
Exothermic products and custom alloys.

F

Fabristeel Products, Inc. 1278
Clinch nuts and diversified fasteners.

FAC Division of Overseas Commodex Corp. 1754
Universal construction kit for making models of machine tools, automation devices, laboratory equipment.

Fahralloy Co. 144
Alloy castings.

Fairchild Engine and Airplane Corp. 915
See Al-Fin Div.

Fansteel Metallurgical Corp. 1615
Nonferrous centrifugal, permanent mold, and sand castings, high-density metal, acid-proof metal, electrical contacts.

Fawick Airflex Div., Fawick Corp. 855
Punch press, clutches, brakes and controls.

Fenn Mfg. Co. 1250
Combination two-high, four-high rolling mill.

Fenway Machine Co., Inc. 126
Portable metal cutting tools.

Ferner Co., Inc., R. Y. 1390
Microscopes and metallographic equipment.

Firth Sterling, Inc. 1450
Tool and die steels, high speed steels, high-temperature alloys, carbide tools.

Flick-Reedy Corp. 1660

Foxboro Co. 1769
Temperature, pressure and process control equipment, flow meters.

Friez Instrument Div., Bendix Aviation Corp. 1481
Fluoroscopic image intensifier for X-ray and betatron work.

G

Gaertner Scientific Corp. 1550
Toolmakers microscopes, comparators, scientific equipment.

Garvin Brothers, Inc. 1282
Power torque tools for driving fasteners, precision products.

Gas Appliance Service, Inc. 754
Gas-fired heating equipment.

General Alloys Co. 548
Heat resisting and stainless steel castings and furnace parts.

General Dynamics Corp. 1642
See Electro Dynamic Div.

General Electric Co., Apparatus Sales Div. 1468
Arc welders and electrodes, recording and measuring instruments for the process industries, laboratory furnaces, induction motors.

General Electric Co., Metallurgical Products Dept. 1368
Carboloy cemented carbide and cemented oxide tool materials.

General Fireproofing Co. 435
Drafting desks and tables, office furniture.

General Ultrasonics Co. 1219
Ultrasonic generators.

Getchell Steel Treating Co., Inc. 1687
Commercial heat treating service.

Goldsmith Bros. Smelting & Refining Co. 1022
Silver brazing alloys and fluxes, precious metals for plating.

Goodrich Aviation Products, B. F. 347
Rivnuts.

Gray Co., Inc. 242
Paint spray equipment, pumps.

Grede Foundries, Inc. 1637
Ductile iron, shell molding, iron and steel castings.

Gregory Industries, Inc. 1476
See Nelson Stud Welding Div.

Gries Reproducer Corp. 1343
Die castings and hardness testers.

Grotnes Machine Works, Inc. 1592
Hydraulic expanders, forming and sizing machines, machine parts.

Gulf Oil Corp. 320
Oils and lubricants for the metal industry.

Guthery Machine Tool Corp. 1692
Machine tools and attachments, portable spot welders.

H

Hacker & Co., Inc., William J. 1254
Metallographic equipment.

Hammond Machinery Builders, Inc. 1311
Grinding machines.

Handy & Harman 1415
Silver brazing alloys, contact alloys, anodes.

Harmon & Co. 1587
See Commercial Shearing and Stamping Co., Inc.

Harper Co., H. M. 1683
Extruded shapes and carbon, alloy and stainless steel and titanium, fastenings.

Harper Electric Furnace Corp. 1683
Electric sintering and brazing furnaces.

Harris Refrigeration Co. 1411
Low-temperature industrial chilling units.

Hastings Raydist Inc. 1785
Vacuum, pressure, velocity and flow measuring instruments.

Hauck Mfg. Co. 947
Oil and gas burners, mixers, valves.

Hayes, Inc., C. I. 1306
Heat treating furnaces, gas burners and generators.

Haynes Stellite Co. 539
Heat and corrosion resistant alloys, investment castings, hard facing materials and cutting tools.

Heintz Mfg. Co. 1875
Cold formed components, chemical surface treatment.

Heli-Coil Corp. 216
Screw thread inserts.

Hevi-Duty Electric Co. 1819
Heat treating equipment.

High Vacuum Equipment Corp. 1377
Laboratory vacuum furnaces, vacuum gage controls, diffusion pumps.

High Voltage Engineering Corp. 325
X-ray generators and particle accelerators.

Hitchiner Mfg. Co., Inc. 319
Precision investment castings.

Hobart Brothers Co. 1251
Electric arc welders; welding supplies and equipment.

Holcroft & Co. 819
Industrial furnaces and gas generators.

Hones, Inc., Charles A. 742
Industrial gas burners.

Houghton & Co., E. F. 1018
Compounds for drawing, cutting and surface treatment of metals.

Howard Foundry Co. 927
Aircraft and commercial quality castings.

I

Illinois Metal Products 1680
Vises and fixtures.

Illinois Testing Laboratories, Inc. 1353
Temperature, air and dew point measuring and controlling instruments.

Induction Heating Corp. 1207
Induction heat generators and hardening machines.

Industrial Heating 1441

Industrial Heating Equipment Co. 1558
Furnaces for metal treating industry.

Industrial Nucleonics Corp. 1274
Foil mill measurement system, equipment packaging, central station process analyzer and automatic data read-out system.

Industrial Press 1361
Machinery; trade papers and engineering books.

Industrial Publishing Corp. 1780
Industry and Welding, Precision Metal Molding, Welding Illustrated.

Industrial Tectonics, Inc. 1121
Special alloy bearings and balls.

Instron Engineering Corp. 1750
Mechanical, universal and creep testing equipment.

Intercontinental Electronics Corp. 110

International Nickel Co., Inc. 542
Nickel and nickel alloys and products.

Ionic Electrostatic Corp. 301
Paint spraying equipment.

Ipsen Industries, Inc. 1606
Heat treating furnaces, production automation equipment, accessories for atmosphere, dew point and carbon potential control.

J

Janney Cylinder Co. 1836
Centrifugal castings and machined products.

Jarrell-Ash Co. 1830
Spectrometers and spectrographs

Jiffy Disintegrators, Inc. 1575
Disintegrator machines for removing broken taps.

Johansson Co., I. O. 928
Drilling machines.

Johnson & Son, Inc., S. C. 1530
Cutting and drawing fluids.

Jomac Inc. 1698
Gloves and protective clothing.

Jones & Laughlin Steel Corp., Strip Steel Div. 1127
Precision cold rolled strip steel.

K

Kanthal Corp. 842
Heating elements and electric resistance alloys.

Kemp Mfg. Co., C. M. 727
Industrial gas combustion equipment, atmosphere equipment. equipment.

Kennametal Inc. 1529
Tungsten and titanium carbide, columbium and tantalum.

Keokuk Steel Casting Co. 1396
Steel castings.

Kerns Co., L. R. 235
Drawing, cutting, grinding and forging compounds.

King Tester Corp. 924
Brinell testing machines and microscopes.

Kinney Mfg. Div., New York Air Brake Co. 1459
Vacuum equipment.

Kirksite Tool & Engineering Div. 1506
See National Lead Co.

Knight Models, Inc. 1650
Three-dimensional model of metalworking plant.

Koehring Co. 1336

Kolcast Industries Inc. 1326
Investment castings and vacuum parts in high-temperature alloys.

Korhumel Steel & Aluminum Co. 226
Warehouse facilities for aluminum and steel products.

Kux Machine Co. 1659
Die-casting machines and powdered metal presses.

L

L & L Mfg. Co. 1284
Electric kilns.

Laboratory Equipment Corp. 1286
Carbon and sulphur analyzers, chemical laboratory equipment.

Lake Chemical Co. 1443
Paint sticks and protective coatings, fluxes.

Admission to Metal Exposition

Badges or membership cards for the cooperating societies listed on p. 66 will admit members to the Exposition at no charge. Visitors with Metal Show invitations from exhibitors will be issued a badge at no charge. Others will be charged a registration fee of $1.00.

Hours of the Exposition

Mon., Tues. & Wed., Nov. 4, 5 and 6—12 noon to 10:30 p.m.
Thurs. and Fri., Nov. 7 and 8—10:00 a.m. to 6:00 p.m.

Lee Co., K. O. 1397
Grinding machines and accessories.

Leeds & Northrup Co. 865
Heat treating (Homocarb) furnaces, temperature measuring and control instruments, gas analyzers.

LeFiell Mfg. Co. 114
Tubular metal parts and fabricated parts for aircraft.

Leitz, Inc., E. 1231
Microscopes and accessories.

Lempco Industrial, Inc. 1740
Grinders and die sets.

Lepel High Frequency Laboratories, Inc. 1848
Induction heating equipment.

Lewis Machine Co. 1418
Wire straightening and cutting machine.

Light Metals Dept., American Brake Shoe Co. 336
High-strength aluminum castings for aircraft.

Lindberg Engineering Co. 620
Welding equipment and supplies.

Linde Co. 539
Oxy-acetylene welding and cutting, flame plating.

Link Engineering Co. 428
Testing equipment, tools and fixtures.

Lobeck Casting Processes Inc. 1649
Billet and slab casting machines and rolls.

Loma Machine Mfg. Co., Inc. 1649
Rolling mills, extrusion and forming presses, cut-off saws.

Lufkin Rule Co. 1807
Precision tools, measuring tapes and rules.

Lynchburg Foundry Co. 920
Ductile and gray iron castings.

M

M. B. I. Export and Import Ltd. 316
Horizontal optical jig borers, precision tools and accessories.

Magnaflux Corp. 1153
Magnaflux and Zyglo nondestructive inspection materials.

Magnetic Analysis Corp. 948
Magnetic analysis equipment.

Magnetic Tool Corp. 1718
Magnetic welding fixtures and tools.

Malayan Tin Bureau 341
Applications of tin in industry.

Mallory-Sharon Titanium Corp. 1525
See Reactive Metals, Inc.

Man-Au-Cycle Corp. of America 1557
Lathes and other machine tools.

Maneo Mfg. Co. 847
Billet shears, rod cutters, tube cutters.

Manufacturers Processing Co. 1844
Vibrating degreasers.

Markal Co. 1443
See Lake Chemical Co.

Martindale Electric Co. 1292
Electrical etchers, circular saws, precision electrical tools and equipment.

Maserati Corp. of America 1605
Machine tools.

Mead Specialties Co. 1640
Air cylinders, air valves, air-operated devices.

Melray Mfg. Co. 1857
Close-tolerance stampings for precision parts and scientific instruments.

Metal Finishing Service 1492
Shot peening and blasting equipment.

Metal Lubricants Co. 1788
Cutting fluids, drawing compounds, quenching fluids, greases and oils.

Metal Powder Association 619
Powder metallurgy applications.

Metal Progress

Metal Removal Co. 1667
All-purpose abrasive.

Metallizing Co. of America 1868
Metallizing equipment.

Metallizing Engineering Co., Inc. 1760
Spray metallizing guns and wire.

Metallurgical Products Dept. 1368
See General Electric Co.

Metals Engineering Institute
Home study and in-plant training courses.

Metals Review

Metalwash Machinery Corp. 734
Metal Cleaning equipment.

Metalworking Publishing Co., Inc. 1891
Metalworking

Met-L-Chek Co. 1395
Flaw-finder and dye penetrant.

Michigan-Standard Alloy Casting Co. 1446
Alloy castings.

Micrometrical Mfg. Co. 1227
Profilometer and other surface control equipment.

Milband Div. 1545
See Henry G. Thompson & Son Co.

Miller Fluid Power Div., Flick-Reedy Corp. 1660

Minneapolis-Honeywell Regulator Co., Industrial Div. 1042
Industrial motors, recorders, controllers, pyrometers.

Minnesota Mining and Mfg. Co. 1212
Heat sealable films, pressure sensitive tapes, tape dispensers.

Mitchell Radiation Products Corp. 1385
Industrial X-ray units, isotope handling equipment, X-ray accessories.

Mitts & Merrill Corp. 1479
Cutting machines.

Modernair Corp. 1879
Fluid power devices, air and hydraulic cylinders.

Monarch Tools, Inc. 1682

Morehouse Machine Co. 1382
Tools and testing machines.

N

NRC Equipment Corp. 1426
Vacuum induction and arc furnaces, vacuum metallizing equipment, gas analyzers.

National Carbon Co. 539
Carbon and graphite products.

National Distillers and Chemical Corp. 1525
See U. S. Industrial Chemicals Co.

National Lead Co. 1506
See Doehler-Jarvis Division.

National Lead Co., Kirksite Tool & Stamping Dept. 1506
Metal-forming dies and punches.

National Malleable and Steel Castings Co. 1735
Malleable iron and steel castings.

National Metal Abrasive Co. 1289
Abrasive shot and grit.

National Plating & Processing Co. 1295
Metal finishing service.

National Research Corp. 1426
See NRC Equipment Corp.

National-Standard Co., Wagner Litho Machinery Div. 1745
Electroplating process, fine speciality wires and wire products, cold rolled speciality strip.

National-U. S. Radiator Corp. 625
See Plastic Metals Division.

National X-Ray Products Corp. 1872
X-ray accessories, film dryer.

Nelson Stud Welding Div. of Gregory Industries, Inc. 1476
Stud welding equipment.

New Hermes Engraving Machine Corp. 1339
Portable and bench-type engraving machine for panels, dials, name plates.

New York Air Brake Co. 1459
See Kinney Mfg. Div.

North American Philips Co., Inc. 1630
See Philips Electronics, Inc.

North American-Viking Drill Co. 1335
High speed and carbon steel tap and twist drill sets.

Nuclear Systems Div. 1715
See Budd Co.

O

Oakite Products, Inc. 247
Materials and equipment for cleaning, finishing, machining and grinding.

Ohio Crankshaft Co., Tocco Division 236
Induction heating equipment.

Ohio Seamless Tube Div. of Copperweld Steel Co. 526
Seamless and electric resistance welded steel tubing, fabricated tubular parts.

Oil-Dyne, Inc. 219
Hydraulic pumps, cylinders, other units.

Olsen Testing Machine Co., Tinius 1346
Testing machines.

Opplem Co., Inc. 1288
Microscopes and metallographs, hardness testing.

Opto-Metric Tools, Inc. 1223
Optical measuring tools.

Oregon Metallurgical Corp. 430
Vacuum melting furnaces, titanium and zirconium ingots and castings.

Osborn Mfg. Co. 1330
Brushmatic machines and industrial brushes.

Overseas Commodex Corp. 1754
See FAC Division.

P

Pacific Industrial Mfg. Co. 1576
Hydraulic press brakes and plate shears.

Pangborn Corp. 1263
Blast cleaning equipment.

Pantex Mfg. Corp. 1598
Steam-spray painting equipment and steam-jet cleaners, process heaters.

Park Chemical Co. 637
Heat treating materials, protective coatings and cutting and grinding fluids.

Parker Co., Charles 841
Machinists vises.

Patterson Machine Co., G. C. 1522
Wire straightening and cut-off machines.

Pedrick Tool & Machine Co. 1853
Bending machines.

Penn Precision Products, Inc. 120
Thin-gage rolled metals.

Penton Publishing Co. 1028
Steel, Machine Design, Foundry, Automation and *New Equipment Digest.*

Perkins Machine Co. 1811
Power presses.

Petersen Oven Co. 1291
See Stramen Furnace & Engineering Div.

Philips Electronics, Inc. 1630
Industrial radiographic equipment, spectrographic equipment, X-ray diffraction unit, accessories.

Phillips Mfg. Co. 825
Metal cleaning equipment.

Picker X-Ray Corp. 959
Industrial X-ray equipment.

Pines Engineering Co., Inc. 1675
Tube fabricating equipment.

Pioneer Aluminum, Inc. 1506
Aluminum tooling plates and chucks.

Plastic Metals Div., National-U. S. Radiator Corp. 625
Metal powders.

Plew Tool Co., Inc. 315
See Weatherhead Co.

Porter Co., Inc., H. K. 1863
See Henry Disston Division.

Portomag, Inc. 1159
Portable magnetic drill press.

Precision Extrusions, Inc. 118
Aluminum extrusions.

Presseo Casting & Mfg. Corp. 142
Cast nonferrous gears.

Process Machinery Div. 1798
See Cincinnati Milling Machine Co.

Production Equipment 1488

Production Machine Co. 210
Centerless grinding machine and surfacing machines.

Prutton Corp. 1522
See Wire Machinery, Inc.

Punch Products Corp. 1759
See Service Machine Co.

Pyrometer Instrument Co., Inc. 1744
Surface, radiation, immersion and indicating pyrometers.

R

Radio Corp. of America 1494

Rankin Bros. Engineering and Sales, Inc. 1684
Grinding machines.

Ransburg Electro-Coating Corp. 160
Electrostatic paint spraying equipment.

Reactive Metals, Inc. 1525
Zirconium and hafnium ingots and mill products.

Rebuilders Machinery Sales, Inc. 928
Rebuilt machine tools and production equipment.

Reliance Electric & Engineering Co. 1656
Electric motors.

Richards Co., J. A. 1497
Multiform benders, electromatic saws, steel rules, die-making equipment.

Riehle Testing Machines Div., American Machine and Metals, Inc. 820
Testing machines.

Rotherm Engineering Co., Inc. 1290
Revolving joints and expansion joints.

Ryerson & Son, Inc., Joseph T. 636
Cut-to-order steel and aluminum sheet.

S

S. & S. Machinery Co. 1559
See Man - Au - Cycle Corp. of America.

Salkover Metal Processing of Illinois, Inc. 140
Brazing service.

Sandex Automation Inc. 1585
Automatic feeds for machine tools.

Sandusky Foundry & Machine Co. 1731
Centrifugal castings of heat, corrosion and abrasion resistant alloys.

Scherr Co., George 1550
Microscopes and inspection equipment.

Scientific Electric 301
See Ionic Electrostatic Corp.

Scott Paper Co. 1890
Towels and industrial wipers.

Scully-Jones and Co. 1791
Tools, chucks and accessories.

Selas Corp. of America 718
Gas heat treating furnaces and burners.

Sentry Co. 150
High speed steel hardening furnace.

Service Diamond Tool Co. 1341
Hardness testing machines and accessories.

Service Machine Co. 1759
Punch presses.

Sheffield Corp. 1645
Transfer machines, micro-hardness testers.

Sheldon Machine Co., Inc. 1864
Variable speed drive lathe with automatic speed selector.

Shell Oil Co. 310
Cutting and quenching oils.

Sieburg Industries, Inc. 1783
See Tensilkut Div.

Sinclair Refining Co. 1475
Quenching, grinding and lubricating oils.

Skil Corp. 1787
Portable power tools.

Smith Welding Equipment Corp. 1867
Torches for cutting, welding and heating, regulators.

Socony Mobil Oil Co., Inc. 1676
Cutting oils and rust preventives.

South Chester Corp. 1027
Rivets and fasteners.

Special Libraries Association, Metals Division
Technical and reference books.

Special Machinery Co., Inc. 1386
Radius cutting machines.

Spee-Flo Co. 1797
Painting equipment.

Spencer Turbine Co. 723
Portable vacuum cleaners, turbo-compressors and pneumatic conveying systems.

Sperry Products, Inc. 1053
Ultrasonic inspection equipment.

Spitfire Tool Co. 1636
Lapping machines.

Stanat Mfg. Co. 1442
Rolling mills.

Standard Electrical Tool Co. 1641
Precision spindles and variable speed grinders.

Standard Oil Co. (Indiana) 1564
Petroleum products.

Stanley Electric Tools Div., Stanley Works 1876
Drills, sanders and grinders.

Star Expansion Central, Inc. 1380
Fasteners.

Starlite Industries Inc. 1889
Industrial diamonds, diamond tools and wheels.

Starrett Co., L. S. 1730
Precision instruments and hand tools.

Steel City Testing Machines, Inc. 1729
Machines to test physical and mechanical properties of metals.

Steel Sales Corp. 530
Rod, strip, sheet, wire and tubing.

Stimpson Co., Inc., Edwin B. 342
Rivets, stampings and screw machine parts.

Stokes Corp., F. J. 631
Powder metal press; vacuum equipment.

Stroman Furnace and Engineering Co., Div. of Peterson Oven Co. 1291

Sun Steel Co. 1591
Sheet, strip, flats, rounds.

Sunbeam Corp., Industrial Furnace Div. 828
Gas carburizing furnace and atmosphere quench equipment.

Sunnen Service Corp. 1490
Precision gages.

Superior Tube Co. 209
Small-diameter metal tubing.

Supreme Products Corp. 1861
Chucks and other attachments for power drills.

Surface Combustion Corp. 516
Gas-fired heat treating furnaces and gas generators, controlled atmosphere equipment.

Swedish Crucible Steel Co. 1843
Steel and alloy castings, magnesium parts.

T

Tapmatic Corp. 1859
Tapping attachments.

Tatnall Measuring Systems Co. 1715
See Budd Co.

Taylor Instrument Companies 1885
Temperature and pressure indicators and controllers.

Technic, Inc. 1025
Plating equipment and supplies.

Tempil Corp. 1041
Temperature indicating materials.

Tensilkut Div., Sieburg Industries, Inc. 1783
Machine tools, remote control equipment, shears, gages.

Texas Co. 365
Cutting and drawing compounds.

Thomas Publishing Co. 249
Thomas' Register of American Manufacturers, Industrial Equipment News.

Thompson & Son Co., Henry G. 1545
Saw blades and tool bits.

Thor Power Tool Co. 436
Portable air and electric tools.

Tiarco Corp. 1767
Process for depositing a hard chromium coat, and tools and machine parts coated by this process.

Tickle Engineering Works, Inc., Arthur 919
Alumicoat and Alumibond process.

Timesavers, Inc. 1342
Automatic feed metal polishers.

Tin Research Institute, Inc. 1048
Information about tin and its applications.

Titanium Metals Corp. of America 260
New titanium alloys.

Tocco Div. 236
See Ohio Crankshaft Co.

Torrington Mfg. Co. 1567
Spring coiling machines and spring testers.

Torsion Balance Co. 936
Automatic hardness tester, microhardness tester, analytical and industrial balances.

Triplett & Barton, Inc. 1829
Industrial X-ray units.

Tru-Seal Div., Flick-Reedy Corp. 1660

Tubular Micrometer Co. 1550
Precision measuring instruments.

Tubular Rivet and Stud Co. 1779
Tubular and split rivets, riveting machines.

Turco Products, Inc. 1367
Aluminum conversion coating, phosphate coatings and chemical milling supplies.

U

Uddeholm Co. of America, Inc. 942
Laboratory equipment.

Union Carbide Corp. 539
See Linde Air Products Co., Electro Metallurgical Co., National Carbon Co., Haynes Stellite Co.

Union Mfg. Co. 841
Hand and power chucks, gray iron castings, die sets.

Unit Process Assemblies, Inc. 1023
Coating thickness testers.

United Scientific Co. 1736
Microscopes and metallographic equipment.

U. S. Chemical Milling Corp. 426
Chemical milling operations on a sub-contract basis.

U. S. Dept. of Commerce
Services to industry.

U. S. Electrical Motors Inc. 1268
Variable speed motors.

U. S. Gypsum Co. 1724
Cements, plaster for precision castings and epoxy resin for industrial tooling.

U. S. Industrial Chemicals Co. Div., National Distillers & Chemical Corp. 1525
Zirconium platelets, titanium and hafnium sponge and platelets.

Universal Castings Corp. 1652
Nonferrous castings.

Universal-Cyclops Steel Corp. 1546
Steel plates, sheets, bars.

Universal Gear & Machine Co. 1230
Gears, machine tools.

Upton Electric Furnace Co. 641
Graphite electrode salt bath furnace.

Utility Supply Co. 1486
Hand calculators.

V

Vanadium-Alloys Steel Co. 326
High speed tool and die steels, tool bits and cold drawn special shapes.

Vanadium Corp. of America 854
Ferro-alloys, metals and chemicals.

Vanguard Engineering Co. 1841
Indoor boom truck.

Vapor Blast Mfg. Co. 1394
Liquid honing machines.

Vascoloy-Ramet Corp. 1615
See Fansteel Metallurgical Corp.

W

Wagner Litho Machinery Div. 1745
See National-Standard Co.

Waldes Kohinoor, Inc. 836
Retaining rings, pliers, assembly and accessory tools.

Wales-Strippit Co. 1749
Sheet metal fabricating and duplicating equipment.

Watson Publications, Inc. 217
Modern Industrial Press, Modern Railroads, Appliance Manufacturer.

Waukee Engineering Co., Inc. 1842
Flowmeters, gas-air mixers and industrial washing machines.

Weatherhead Co. 315
Industrial fittings and hose, cutting tools and toolsteels.

Wells Mfg. Corp. 1775
Metal cutting band saws.

Weltronic Co. 1860
Welding positioner motor controls, industrial relays and magnetic contactors, induction generator.

West Instrument Corp. 1060
Temperature controllers, indicators and recorders, other process controllers.

Western Gold and Platinum Co. 1257
Precious metals, brazing alloys, alumina ceramics, super refractories.

Westinghouse Electric Corp. 1616
Arc welding equipment, arc vacuum melting furnace, high-frequency heat treating equipment, motors, brazing alloys.

Weston Electrical Instrument Corp. 248
Recorders and controllers, tachometers, generators and indicators.

Wheelabrator Corp. 1430
Blast cleaning and tumbling equipment.

Wheelco Instruments Div. 941
See Barber Colman Co.

Wilson Mechanical Instrument Div., American Chain & Cable Co., Inc. 953
Rockwell and Tukon hardness testers.

Wire Machinery, Inc. 1522
Wire straightening and cut-off and thread rolling machines.

Yale & Towne Mfg. Co., Powdered Metal Products Div. 1776
Powder metal parts.

Z

Zaco Laboratories 139

Zeiss, Inc., Carl 965
Microscopes and metallographic equipment.

Zenith Foundry Co. 1137
Gray iron and alloy iron castings.

Ziv Steel & Wire Co. 1381
Castings, stampings, toolsteel, punches and dies.

Economics of the New Iron Ore Reduction Processes

*By E. C. WRIGHT**

A ton of steel from all direct iron processes requires at least 4,000,000 Btu. more energy than from the conventional blast furnace and openhearth, and consequently a direct iron plant must be located where electricity or gas is very cheap and coke is very dear. There is little difference in capital costs per ton of product per year. (D8, B15; Fe, RM-n)

IF A MODERN METALLURGIST were to examine the old methods of ironmaking he would say that they were all closely related to the "direct" processes which have received a good deal of attention in the last 20 years. The ancient processes seem to have been invented in many places long ago – certainly before the birth of Christ – and naturally had many variations. From a modern standpoint they all had at least three shortcomings – the hearths had small capacity, the product was quite irregular in quality, and they could not attain the melting temperature of steel.

These old processes were on the way out in the early 14th Century when the Bohemians invented the *hoch ofen*, the true blast furnace. Its molten product was vastly more uniform and was directly useful for iron castings, or for refining into wrought iron and (after Bessemer's day) into steel. Truly the blast furnace has been basic to our industrial and mechanical civilization. Its details have been perfected in many ways, its size greatly increased, its daily output enlarged even more, and its thermal efficiency improved.

It has become almost too good! It is costly to build and even costlier is the auxiliary equipment to convert the great tonnage of pig iron constantly coming from it into castings or steel shapes. These in turn must find a ready market in the neighborhood. The furnace requires good-quality coke for fuel, and this is becoming scarcer and more expensive. It requires fairly high-grade iron ore, else the slag fall becomes burdensome. A large quantity of cooling water is necessary. Obviously there are many places in the world where ore deposits, coking coal, and market are not in fairly close proximity, yet where there would be a demand for a plant producing metal in smaller quantities than one modern blast furnace makes – say, a few hundred tons a day.

These considerations, together with the steady exhaustion of our cheap, good ores and suitable coal deposits, have led many men in the iron and steel industry both in the United States and abroad to turn their attention to the fundamentals of the ancient processes – the so-called

*Consulting Editor, *Metal Progress*, and head of the department of metallurgical engineering, University of Alabama. From 1926 to 1947 Mr. Wright was metallurgist for National Tube Co., at time of resignation being assistant to the president.

direct reduction of ore. With our modern knowledge of science and our techniques of control it might be possible to produce iron uniformly with much less of the carbon, silicon, sulphur and phosphorus which normal pig iron carries. Capital costs might even be less per ton with the simpler equipment. Iron oxide can be reduced to metal at temperatures well below melting, and the unreduced particles and gangue separated magnetically, leaving a fine iron powder of high purity. This might even produce a superior quality of steel. All in all, this might be a simpler, better and cheaper method of extracting iron from its ores.

It just doesn't work out that way – at least under the economic conditions existing in American heavy industry in 1957.

Quality of Raw Materials

The recent revival of interest in direct reduction processes – in spite of the many financial and engineering fiascos in America during the past 30 years – has mainly taken place outside of the United States and in special situations related to low-grade iron ores, absence of good coking coal, freight charges on necessary raw materials, availability of cheap electric power and other unique economic factors. In Canada, with relatively low consuming capacity, but with enormous amounts of cheap, good ore and natural gas, the interest is in producing a 90% + iron which will stand the shipping charges to a foreign consumer. In the United States, interest is spurred by the steady depletion of high-grade iron ores, increases in the cost of blast furnace coke, and the probability that lower and lower grades of iron ore must be handled at high cost in blast furnaces! An additional factor in the American scene is the increased supply of high-grade magnetite concentrates (60% or more iron and less than 10% gangue) plus the huge imports to be expected of rich Labrador and Venezuelan ores. Thus the interest in direct iron is closely connected to the availability of high-grade material. Might it not be more readily handled by direct reduction processes instead of the blast furnace?

Estimates which I think are realistic show that between 15 and 20 million tons per year of 60 to 65% concentrates (magnetite) will be available from taconite deposits in the Lake Superior region, and from mines in the Adirondacks, Canada, and Pennsylvania within the next few years. An even greater annual tonnage of first-class ore is also probable from the new Venezuelan and Labrador ore deposits. These new

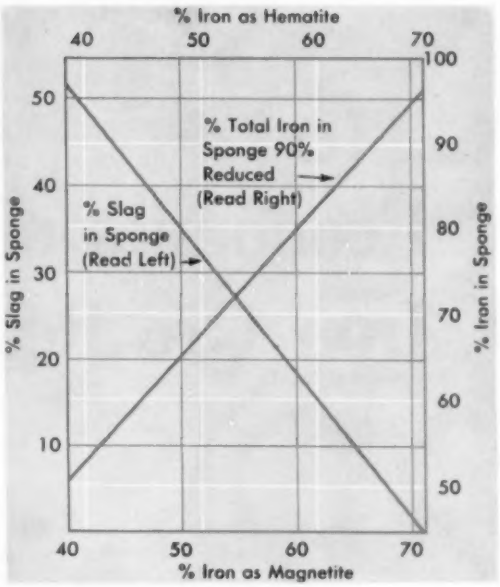


Fig. 1 – Relation of Percentage of Iron in the Ore and Analysis of Sponge in Iron and Nonmetallics

supplies will approximate 40% of American iron ore requirements. These rich ores are easily reduced by hydrogen or carbon monoxide and the very small amount of gangue (2 to 10%) is then separated from the reduced iron powder. Why smelt such material in a blast furnace when the gangue in the ore often weighs less than the ash in the coke required?

On the other side of the picture are the large and numerous deposits of low-grade ores (25 to 40% Fe) which cannot be successfully concentrated at the present time, are too low in grade for direct smelting in blast furnaces, and which are often located near steel consuming regions. These are the hematitic taconites of Minnesota, the jaspers of Wisconsin and Michigan, the ferruginous sandstones of the southern Appalachians in Alabama and Tennessee, the East Texas limonites and siderites. There are billions of tons of iron in these deposits. Furthermore, most of these deposits may be stripped and mined from open pits at low cost. Of course, some of these may be concentrated and the high-grade product shipped to present blast furnaces. Alternatively, if the low-grade ore is reduced directly at a plant adjacent to the mine, and the iron then separated from the gangue, high shipping charges on raw ore are avoided in this manner as well. Coal, fuel oil, or natural gas is usually no more costly at these situations

than at existing steel plants, with the possible exception of the Lake Superior region. The iron minerals – hematite, limonite or siderite, or mixtures of all three – cannot be successfully concentrated by commercial ore dressing methods now known. As a result, these deposits have been largely dormant.

The high-grade Mesabi ores, which have been our chief source, will soon be mined out. The latest available reports of reserves in the Lake Superior district indicate that only about 600 million tons of direct shipping ore remain. Shipments have averaged over 80 million tons per year for the past eight years. Obviously, if this rate continues for another ten years most of the ore supply of the United States will have to come largely from the other sources mentioned above. This of course is responsible for the large concentrating plants now operating in the Lake iron ore region, as described in *Metal Progress* for October 1956.

Some of these low-grade ores may be readily reduced by mixing with coal, or reducing with CO or hydrogen gas. These lean ores are not satisfactory for fluo-solids manipulations* because of the large gangue content (30 to 50%) but have been successfully reduced in rotary kilns, sintering machines, or shaft furnaces. The ores may be partially reduced to magnetite at moderate temperatures, 1200° F., and then concentrated with magnetic separators; they may be partially reduced to iron or FeO at 1800° F. and then smelted to pig iron in electric furnaces; they may be reduced to sponge iron at very high temperatures, 2300° F., in rotary or tunnel kilns. Active work on all of these schemes is going on in pilot plants at several places throughout the world.

Some Difficulties With Lean Ores

The direct reduction of these low-grade ores to the magnetic oxide Fe_3O_4 or to iron powder may usually be accomplished but the separation of the reduced material from the nonmetallic gangue is often difficult. This is partly due to the fact that particles of gangue stick tightly to the magnetite or iron particle. Partial roasting to form magnetite in the hematitic taconites and jaspers of the Lake Superior district does not seem too satisfactory so far; the concentrate is high in silica.

A similar disappointing result was reached several years ago with a magnetic roast on the high-silica ores of Red Mountain in the Alabama district. Pilot plant research on this tough problem still continues; a solution would be of greatest importance, especially in any emergency when supplies of foreign ores would be curtailed. Investigators at Illinois Institute of Technology encountered this difficulty in the partial reduction of several kinds of iron ore and reported failure to get a satisfactory result. M. Tennenbaum reported in the 1951 Yearbook of the American Iron & Steel Institute (p. 208) that "under conditions of fluo-solids bed with hydrogen gas as reducing agent, complete reduction was seldom approached and never attained". Temperatures from 850 to 1800° F. were used in this investigation.

Many of the old sponge iron plants have reached a similar result. John Stalhed, manager of Stora Kopparberg, the largest Swedish sponge iron plant, states in one of his numerous publications: "An ore of the lowest possible gangue content should be used as raw material for sponge iron. Moreover, experience has shown that the lower the gangue content of the ore, the higher the degree of reduction will be obtained in the sponge." Figure 1, taken from one of his papers, shows the important relations between the amount of gangue in the ore and the composition of the iron reduced to sponge at 2300° F. A low-grade ore means that the sponge contains more nonmetallics – also that a smaller portion of the original iron oxide, either as hematite or magnetite, is reduced. The Wiberg-Soderfors sponge iron plants* use lump ore or large pellets in the charge and the reducing gases apparently don't penetrate to the interior of the lumps while they are in the shaft furnace, so the iron oxides are not completely reduced when the gangue content of the ore is very high.

Thus the processing of low-grade ores presents about as many problems as there are ore deposits. Electric smelting of such low-grade ores would be almost a last resort since the high slag volume would waste so much energy.

The R-N process, recently in the news, is the child of Republic Steel Corp. and National Lead Co. Although no information has been pub-

*The "fluo-solids" treatment may be briefly described as it is utilized in the "H-iron process". In it a batch of the finely ground ore preheated to about 900° F. is pumped into a vertical cylinder and pressure of hydrogen run up to about 400 psi. Hot dry hydrogen is forced into the bottom at such a rate that the fines are buoyed up in the gas, yet most of the gas goes upward in small bubbles. This rapidly agitates the solid and gives plenty of contact between oxide (ore) and reducer (hydrogen).

*An analysis of the costs of iron from a Wiberg-Soderfors furnace was presented by P. E. Cavanagh in *Metal Progress* for May 1950, p. 633.

lished on the project which the present writer considers to be reliable, and the people who should know have refused to discuss the subject, it is understood in the Birmingham district that an iron-bearing sandstone carrying 25 to 30% iron and located on Red Mountain is being mixed with coal and fired to a high temperature (possibly 2300° F.) in a rotary kiln. The hot clinker is quenched in water, ground fine in ball mills, and passed over magnetic separators. No information is available as to the degree of reduction attained nor the yield of iron obtained from the original ore charge. The product obtained is then briquetted and charged into steel furnaces.

If the above is reasonably close to the situation, the briquettes might be considered as a low-grade scrap or as a high grade of charge ore containing sufficient oxide content to react with some of the impurities in the pig iron in the steel melting furnace. The open pit mine will produce cheap ore, and if this operation is able to produce a high-quality iron powder it should reduce shipping costs from mine to steel plant, and so be competitive with other iron ores available to the Birmingham district. It will be remembered that the ores in this district are rather low in grade by northern standards.

This again demonstrates the influence of cheap mining costs and the geographic factor on any given situation. However, as far as I have been able to appraise this process it closely resembles the Krupp-Renn process which had a ruinously high fuel consumption. (See *Metal Progress*, April 1950, p. 510, and May 1950, p. 635.) Several Krupp-Renn plants are operating in Europe on very low-grade ores, where they are successful because of the balling action on the powdered iron at 2600° F. and the very friable, high-silica slag produced. The iron balls, 3 to 10 mm. (0.12 to 0.39 in.) in diameter, are cleanly and easily separated from the very glassy slag. Recovery of iron is high.

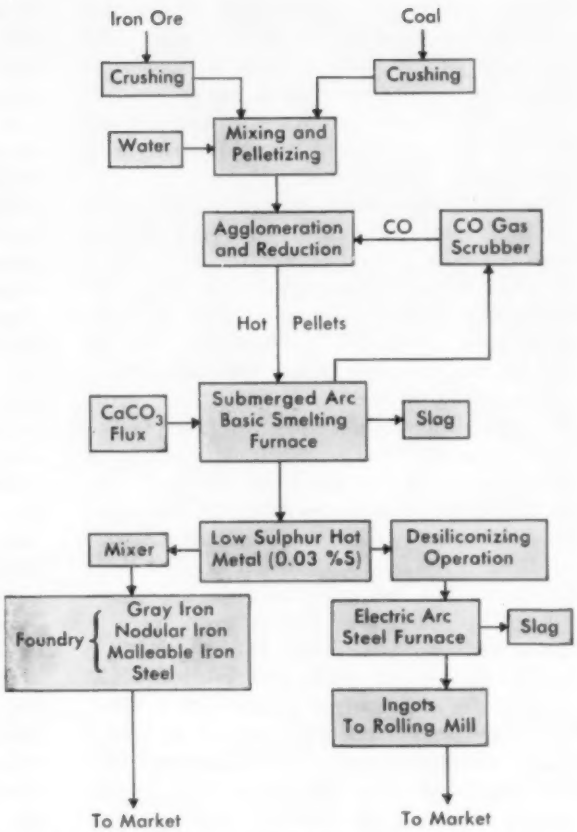


Fig. 2 – Flow Sheet of Plant Using Pre-Reduced Ore Followed by Direct Smelting to Pig Iron in a Submerged-Arc Electric Furnace With Basic Lining. (From F. C. Collin and O. A. Grytting, Journal of Metals, *October 1956)*

Energy Requirements

All of the several direct reduction processes require more energy per ton of molten iron than does the blast furnace, since the product must be heated twice before it becomes a molten steel. Thus, the sponge iron, "H-iron", and "R-N iron" must be heated as ore to the required reduction temperatures, the whole mass cooled to room temperature for the separation of the powdered iron, and the latter is then reheated past the melting point of steel. In contrast, when hot metal is charged into the steel furnace directly, most of the sensible heat of the molten iron is saved. Rough calculations of the heat balance of the various processes indicate a net heat requirement of the following amounts, when all are operating on an ore containing 65% iron:

H-iron	18,500,000 Btu. per ton melted
Sponge iron	13,000,000
R-N process	15,300,000
Electrokemisk	11,000,000
Blast furnace	11,400,000

The differences range between 1,600,000 and 7,100,000 Btu., and at 70¢ per million this amounts to a cost differential of $1.12 to $5.00 per ton of melted product. This factor is re-

flected in the Swedish Wiberg-Soderfors sponge iron and the Norwegian Electrokemisk processes, where 850 and 1200 kw-hr. per ton of iron respectively is used. The thermal efficiency of electric power heating is better than 70% whereas combustion of fuels is more nearly 20% without regeneration.

In the Electrokemisk process (Fig. 2), hot pre-reduced ore is smelted electrically. It equals the blast furnace in thermal efficiency as it saves the sensible heat of the pre-reduced ore, and recovers the CO gas from the furnace to supply some of the energy required for heating the ore in the pre-reduction kiln. On the other hand, the Wiberg-Soderfors furnace is charged with cold ore and the iron mineral (about 90% of it reduced to iron) plus gangue is cooled to 300° F. before being withdrawn from the furnace.

It is obvious that any direct smelting method will always have an advantage over any of the iron powder processes equal to the heat content of a ton of steel at its melting point. This is about 1,200,000 Btu. If it is supplied by combustion of fuel with regeneration, the over-all efficiency is only about 25%. Thus a differential in favor of the smelting methods will remain at about 4,000,000 to 5,000,000 Btu. (It should be noted that this discussion is based on 65% iron ore; lower grades of ore would require an entirely new set of calculations.)

Over-all Economics

Current magazines have carried many descriptions of these developments, and some very elaborate and even fantastic claims have been made for them. This has been particularly evident in nontechnical publications, such as the article by E. L. Van Dusen in *Fortune* for October 1956, where the doom of the blast furnace has been freely predicted. It is frequently claimed that the capital cost of these direct reduction plants per ton of iron produced is about half of that for a new blast furnace and necessary coke plant.

The present writer has personally discussed this matter with men on the research and development staffs of prominent steel companies, who are studying all of these proposals intensively, and also with engineering firms that design and erect plants. It appears that these optimistic claims are not justified.

Let us first consider the newly proposed processes. At present the general opinion of these American steelmen is that a brand new direct reduction plant of 1000 tons daily capacity would cost at least $20,000,000. Part of this is due to the multiplicity of production lines required for such an output. For example, in the electric smelting of pre-reduced ore, the largest submerged-arc smelting furnace produces only about 400 tons of pig iron per day. (It is 32 ft. in diameter, equipped with 45-in. carbon electrodes and requires 20,000-kw. electrical supply.) Thus at least three production lines would be needed for the desired output. A similar situation would exist for the equipment needed in the complicated H-iron flow sheet*, R-N process, or the Wiberg-Soderfors sponge iron plant. Two large engineering firms have estimated a cost of $7,000,000 to $9,000,000 for a production line with a 400-ton per day capacity for some of these proposed direct reduction plants. This comes to $57 per annual ton of iron.

On the other hand, blast furnaces with hearth diameter of 28 ft. have recently been built at actual cost of $30,000,000 to $40,000,000 with all accessories, including coke plant. The lower figure applies to units built as additions to existing furnace plants or replacing older smaller furnaces, while the higher figure represents new installations at new locations. Such a furnace will produce 1500 tons of iron per day from Lake Superior ores (50% Fe) and over 2000 tons per day with taconite pellets or foreign ores containing over 60% Fe. Even at present price levels, modern blast furnaces have been built and are operating successfully at a capital cost of $55 to $60 per annual ton of pig iron. Remember that this iron is already melted, ready for the steel refining furnace.

The best present opinion on the capital cost debate seems to be that there is little difference in capital costs for all of the five methods of producing iron. If there is any definite choice, many steelmen feel that the blast furnace is still tops, since they *know* its capital and actual operating costs, while the figures for the other processes (expect the Swedish sponge iron) are based on speculative estimates extrapolated from data for small pilot plants.

Some idea of the operating cycles and equipment needed in these direct reduction plants may be gained from published flow sheets. Collins and Grytting, in *Journal of Metals* for October 1956, estimate that the pre-reduced ore-electric smelting process requires the crushing of three tons of ore and 1 ton of coal. This mixture may then be pelletized and heated to 1800 to 2000° F. in shaft furnaces, sintering

*The H-iron process requires at least 13 different items of equipment for such operations as making hydrogen, preheating ore, reducing ore.

machines, or rotary kilns to remove over half of the oxygen from the iron oxide, yielding a product containing iron, FeO, carbon plus the gangue of the ore and the coal ash. (Sufficient carbon must remain in the fired pellet to complete the reduction of the FeO in the electric furnace.) The hot product is charged into the submerged arc smelting furnace with sufficient lime or dolomite for fluxing the gangue, and molten pig iron and slag are produced. A large volume of CO gas escapes the smelting furnace and should be recovered and used for heating the ore mixture in the pre-reduction furnace. The basic slag and lining of the electric smelting furnace yield low-sulphur metal (under 0.03% S). Figure 2 shows a simplified flow sheet of this type of plant which is now operating in Norway on a high-grade ore containing 60% Fe. The iron analysis varies considerably due to the difficulty in controlling the degree of pre-reduction in the agglomerating step and the range of carbon in the pellets.

The H-iron process has received much publicity and many claims have been made as to its high-quality product, low production cost, and small capital cost. A description of operations in a pilot plant built and operated jointly by Bethlehem Steel Co. and Hydrocarbon Research, Inc., was given by A. M. Squires and C. A. Johnson before the A.I.M.E.'s Blast Furnace, Coke Oven and Raw Materials Conference in April 1957. The process is quite complicated and involves the handling of hydrogen gas at pressures of 400 lb. and temperatures up to 1000° F. A flow sheet is shown in Fig. 3.

It All Depends!

To summarize this complicated situation: There is no doubt that the direct reduction of high-grade iron ores is technically feasible. It seems probable that the installation of plants will depend largely on geographic and economic factors. There will always be places (like ancient Rio Tinto) where iron is a byproduct of operations necessary for the extraction of other metals of higher value. Logical locations for direct iron plants would be those where cheaply mined, rich ore deposits are near coal or natural gas, yet where good coke is not available. Where ore may be mined by open-pit stripping instead of underground, the low cost of ore might offset the higher energy consumption of direct reduction plants. For example, a scheme such as the H-iron process would be favored by cheap natural gas in Texas, or waste gases from huge oil refineries as in the Chicago district.

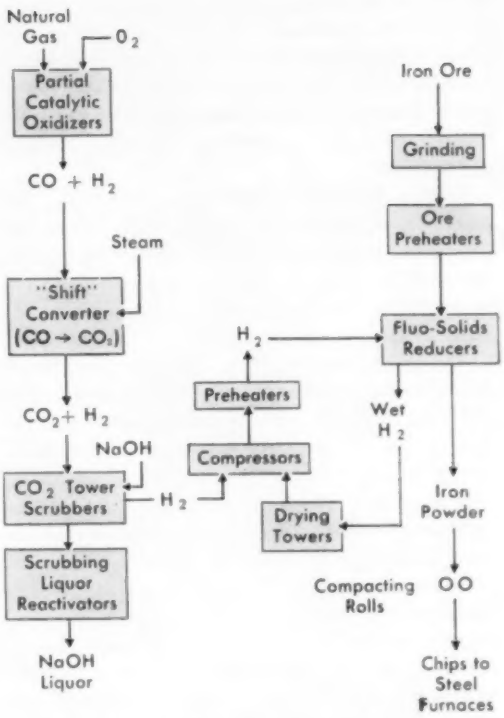


Fig. 3 -- Flow Sheet of "H-Iron" Process

One attractive feature of the direct reduction schemes is that plants could be built with small capacities of 100 tons or more per day. Non-integrated steel producers could thus obtain 100 to 400 tons of powder iron or hot metal per day to feed their steel furnaces at a lower cost than purchased scrap or cold pig iron. Large iron and steel foundries could also obtain cheaper supplies of iron whenever their consumption of iron would exceed 400 tons per day. On the other hand, the direct electric melting of scrap in furnaces of moderate size has already proven to be quite profitable – even in the Birmingham region where a large integrated industry flourishes.

At present this seems to be the most logical type of plant to take advantage of these developments – the small outfit in regions favored by cheap ore and cheap energy – somewhat isolated or at least far distant from established steel plants, and having a moderate market for an easily produced line. It still looks like the large integrated steel producers will stick to the blast furnace, except in locations such as the above where good coke and water supply are unavailable and where hot metal requirements are not too great.

Atomic Fuels

*By FRANK H. SPEDDING**

Several fissionable isotopes will be available to fuel the future power reactors, and could be used as solid metal or alloy, as a molten mixture or in liquid solution. Various coolants and moderators are also possible. To determine which combination of all these can best produce economical electricity is the aim of the Atomic Energy Commission's extensive and costly developmental program. It will require years of hard work by metallurgists and other engineers. (T11g, W11p; U, Th, 14-13)

DESIGN AND PREPARATION of nuclear fuels for power reactors is an extremely complex topic. Theoretically, the fuel can be in either the solid, liquid, or even the gaseous state. It can be introduced into the reactor as a metal, an alloy, an oxide, a carbide, a ceramic, a molten metal solution, a fused salt solution, or as an aqueous liquid solution. Since the fuel can contain various concentrations of several fissionable atoms, and can be introduced into the reactor in various shapes or configurations, there is almost an infinite number of ways in which the fuel could be prepared.

Cost of Fuel and Fuel Cycle

One of the most persistent erroneous ideas concerning nuclear power is that the fuel is of negligible cost. This misconception arises from the fact that nuclear fuels are cheap – *provided* some assumptions are made. If one takes $20.00 per lb. as a price for uranium, and assumes that it can *all* be fissioned in a breeder, then an apparent fuel cost of about 0.005 mill per kw-hr. for electricity can be computed.

Nothing could be further from the truth.

It is true that it is potentially possible to get the costs of the entire fuel cycle in the nuclear power plant well below fuel costs in conventional steam power plants, but this is yet to be achieved. The fuel costs have to be calculated not on the basis of introducing a certain quantity of fission-

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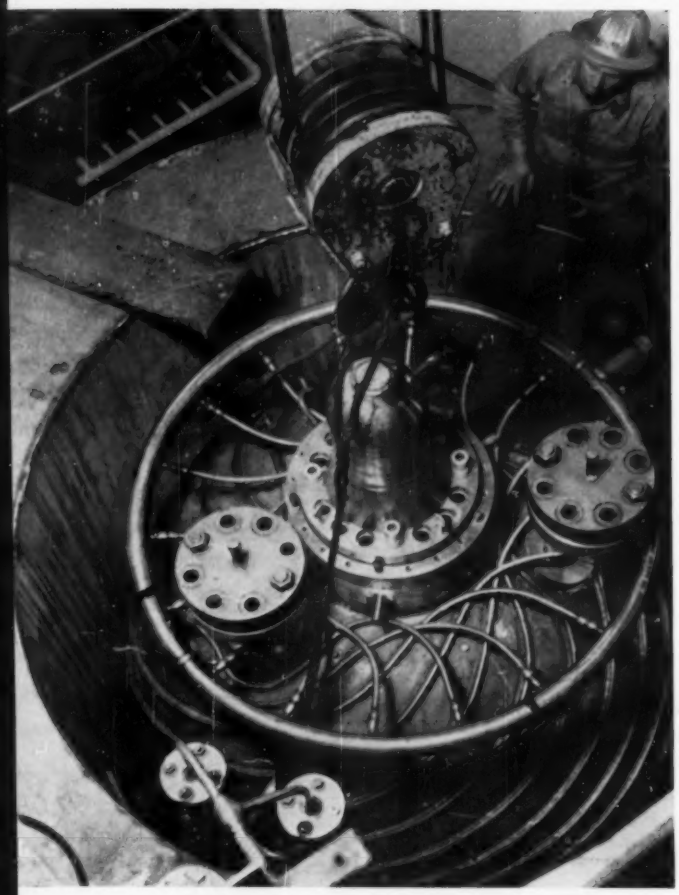

Fig. 1 — Core of A.E.C.'s Homogeneous Reactor Experiment No. 2 at Oak Ridge, Generating up to 10,000 Kw. of Heat and 2500 Kw. of Electricity. The sphere with spiral cooling coils is a blast shield made of ¼-in. thick stainless steel. Inside is a pressure sphere, 5 ft. 9 in. diameter, of carbon steel 4 in. thick clad inside with ⅛-in. stainless steel. The core (containing the fuel solution) is still an inner sphere, 32 in. diameter of zirconium alloy 0.31 in. thick. Surrounding the zirconium is a blanket solution. Both solutions are at 2000 psi. pressure to prevent boiling

able material into the reactor, but on the basis of introducing a certain quantity which will be consumed in producing useful heat. It is necessary, therefore, to add to the first cost of the metal the costs of preparing the fuel element and the costs of extracting and disposing of the waste materials — costs which can be, and frequently are, quite high. It should be emphasized in addition that the manner in which the fuel cycle* is carried out can drastically influence the design of the reactor and the capital investment.

Variables in Reactor Design

A considerable number of nuclear reactors have now been built, and much information has been published on the fuel elements used in these reactors.† From this accumulated experience, we have learned a great deal as to what can and what cannot be done. However, we are as yet in no position to say which reactors will be the most efficient or economical. Even the experts who have been working in this field since the beginning cannot agree as to which type is the most promising, let alone what variation of the type would lead to the cheapest atomic power. A great deal of basic research in the fields of chemistry, physics, metallurgy, engineering, and even biology, will have to be done before this problem can be settled, and a considerable number of prototype reactors will have to be built and operated before even many of the drastically different *types* of reactors can be eliminated from the competition for producing cheap atomic power. This is the basis of the very extensive reactor development program in the U.S. Atomic Energy Commission.

It is becoming increasingly clear that no single type of reactor will be superior for all purposes, and that the form of the fuel used will be different for each type of reactor designed. The most economical power plants for producing 10,000 kw. of electricity will most certainly be different in design from those built to produce 100,000 or 1,000,000 kw., and the fuel would have to be prepared in a different manner for each type.

Certain questions will profoundly influence the entire design and, therefore, the fuel assemblies used. For example, is the plant to be located in a densely populated area where supersafety plays a dominant role, or is to be located in a sparsely populated area where smaller safety factors can be tolerated? What is the fundamental purpose of the reactor? Is the reactor to produce power only, or is it expected to produce fissionable materials as a by-product for weapons or for enriching the fuel for other

*By "fuel cycle" is meant all those operations required to prepare the metal in such form as is required for the particular power plant, handling and storage costs between factory and power plant (including spares or reserve supply), installation in reactor, removal after economical amount of "burn up", protection and shipment to processing plant, recovery of unreacted material and valuable by-products, and disposal of radioactive wastes.

†For example, see the technical papers of the International Conference on the Peaceful Uses of Atomic Energy at Geneva, Aug. 8 to 20, 1955.

reactors? Answers to these will decidedly affect the cost of the power.

As far as I know, every power reactor which has been designed to date utilizes the fuel in a somewhat different manner, and has its own problems regarding the preparation of the fuel assembly. Developments are occurring so rapidly that long before the power plant is complete, the fuel assembly and cycle are obsolescent, and designers of future reactors would be very unlikely to duplicate them exactly. This doesn't mean that once a power plant is built it can't be used to produce economic power, since the initial investment is already made and the continued operation of the plant would not be uneconomical in comparison with conventional fuels, but it does mean that future construction, for some time to come, will not duplicate that of the existing designs.

The state of development of the atomic industry in a given country can also play a dominant role in the design of the reactor and fuel assemblies. When natural uranium has to be used without enrichment with readily fissionable isotopes or elements, and such auxiliary materials as heavy water, zirconium and beryllium are very expensive or unattainable, the fuel assembly to produce the most economical power will be very different from that which would be used in those countries where the desirable materials are available. The ratio of the cost of fissionable material (U^{235}, U^{233} or Pu^{239}) to the cost of the source materials (natural uranium or thorium) is one of the dominant factors in determining the type of fuel assembly and the cost of power. This ratio is certain to get smaller as the atomic industry develops. Therefore the most economical fuel element assemblies today will not be the most economical ones in the future.

Aside from the fuel element, the manner in which an entire nuclear power plant will be designed will also change markedly as experience accumulates. When natural uranium is used for the source of heat, conditions needed to get a chain reaction going are very critical. The materials in the reactor have to be of very high purity and placed with exact geometry. However, as enriched fuels become available, these conditions can be greatly relaxed. While new problems will arise, they can be solved and not interfere with the production of more economic power.

At this stage of development, the economic factors will play a much greater role. The design of the reactor will be more and more determined by what the metallurgists, chemical engineers and power engineers say are the most economical ways to construct the reactor and fuel assemblies. In other words, as enriched materials are used, the drastic limitations on purity and types of materials and the geometry of the reactor are greatly relaxed. The power plant can then be designed to take advantage of cheaper materials for construction and of cheaper processes for preparing the fuel.

Uranium and Thorium

Uranium and thorium are the two metals naturally occurring in the earth's crust useful for atomic fuel. They exist in many minerals, and these minerals may be fairly concentrated or may be highly diluted with other material. (Most of the thorium is obtained from the mineral monazite.) One of the first operations after mining the ore is to concentrate the uranium-bearing minerals, and this is done by such conventional operations as crushing, magnetic separation, flotation, and the use of wetting agents which preferentially influence the settling rate of the various minerals. Each ore presents its own problems and the processes used vary widely from mine to mine. Recovery of purified uranium metal from the concentrate now requires methods and equipment far more familiar to chemical engineers than to metallurgists. Even the final conversion from purified chemical compound to metal is rather unusual and utilizes calcium or magnesium as a reducing agent in a closed vessel. Subsequent fabrication of the ingot, as by rolling, extrusion, machining, and powder metallurgical methods, is fairly conventional. The scrap is valuable so it is carefully husbanded. The uranium content of the ores may vary from a few parts per million up to several parts per hundred, so the costs of extracting and purifying may vary from a very few dollars up to hundreds of dollars per pound.

Reports on the known resources of uranium in the world indicate that there is sufficient economically recoverable uranium to satisfy the anticipated world power demands for at least the next millennium. It is also reported that there is more thorium in the world than uranium.

Some Elementary Physics

In a paper of this length, it is obviously impossible to describe all the possible ways of producing fuel elements. Therefore the remainder of the paper will be devoted to some of the factors which have to be considered in

connection with a specific reactor design and the planning of a suitable fuel assembly. This depends fundamentally on the conditions under which atomic fission occurs, and so it might be well to introduce some elementary physics, at the risk of boring some readers more familiar with this fascinating subject.

The uranium occurring in nature is made up of several isotopes (atoms that have the same chemical properties but whose nuclei are different in mass and nuclear properties) but mostly of atoms having masses of 235 and 238 on the atomic weight scale. In normal uranium, there are about 140 U^{238} atoms to each U^{235} atom.

If neutrons pass near a U^{235} nucleus, there is a certain probability that one will be captured and a U^{236} nucleus will be formed. This is unstable and immediately explodes or fissions to give more neutrons and the two very intensely radioactive lighter elements known as the fission products. These newly freed neutrons, in turn, if they are captured by other U^{235} atoms, can cause them to fission and thereby set up the chain reaction. If the chain reaction is to be maintained, as many neutrons in the next generation must produce fission as caused explosions in the previous generations. If less fissions are produced in succeeding generations, the chain reaction will die out; if more are produced, the reactor will run away.

One important way of influencing the probability of neutron capture by the fissionable atoms is by geometry – that is to say, where the U^{235} atoms are located in the reactor. This can be done by diluting them with other atoms which do not fission. Consequently, the concentration of the U^{235} is frequently varied in fuel assemblies for different reactor designs; furthermore the original concentration will spontaneously change as the reactor is operated since the U^{235} will be consumed.

Enriched Fuel

Another important way of increasing the probability of neutron capture is to enrich the natural uranium with U^{235}. This can be separated from normal uranium by the well-known diffusion process. The U^{235}, however, is expensive and can decidedly influence the cost of power production.

The probability that a neutron will be captured if it goes near a U^{235} atom is also influenced by the velocity with which it is traveling. On first liberation they have high energies and they will not be captured by a neighboring U^{235} atom as readily as they will when they are traveling at a slower velocity. For this reason, moderators (materials containing light atoms such as heavy hydrogen in "heavy water", beryllium and carbon – none of which have much tendency to capture neutrons) are frequently used to slow down, through collision, the average velocity of the neutrons. Sometimes it is desirable to mix these moderators intimately with the fissionable material to be fed in the fuel cycles, so alloys or solutions will be made up from the mixture. We may then have a homogeneous reactor. On the other hand, it may be desirable to let the fast neutrons escape from the individual fuel elements to be later slowed down by a moderator placed between the elements. The slow neutrons will then be captured by atoms in neighboring fuel elements. This results in a heterogeneous reactor and here, again, it can be seen that geometry plays an important role.

If the neutrons are not slowed down appreciably, the U^{235} content has to be higher to maintain the chain reaction and we have a "fast reactor". If they are slowed down partially, we refer to it as an "intermediate reactor" and if they are slowed down so as to be in thermal equilibrium with the reactor, we refer to it as a "thermal reactor". In each type of power plant, the fuel elements would be distinctly different.

If the neutron passes near a U^{238} atom, there is also a probability (again varying with its speed) that it will be captured and form an atom of U^{239}, which explodes in a different manner, giving out no neutrons and comparatively little heat. After an intermediate decay, another fuel isotope, Pu^{239}, is produced. The rate at which this occurs is slow, so that after about 2.3 days only half the U^{239} atoms formed will be converted to Pu^{239}. The latter are also fissionable, and as they build up in the reactor they can take the place of the original U^{235} atoms in maintaining the chain reaction. If the U^{238} captures enough neutrons to produce more Pu^{239} atoms than U^{235} atoms from which the neutrons came, then we say the reactor is a "breeder" and we are burning U^{238} as a fuel. If less plutonium atoms are formed than U^{235} atoms consumed, they will supplement the amount of energy produced, but ultimately the reactor will die out, leaving a large quantity of U^{238} which is not consumed. In this case we refer to the reactor as a "converter" in which we make plutonium from U^{238} at the expense of U^{235}. As the Pu^{239} builds up in the fuel element, a certain fraction of it will be converted to Pu^{240}, an atom which

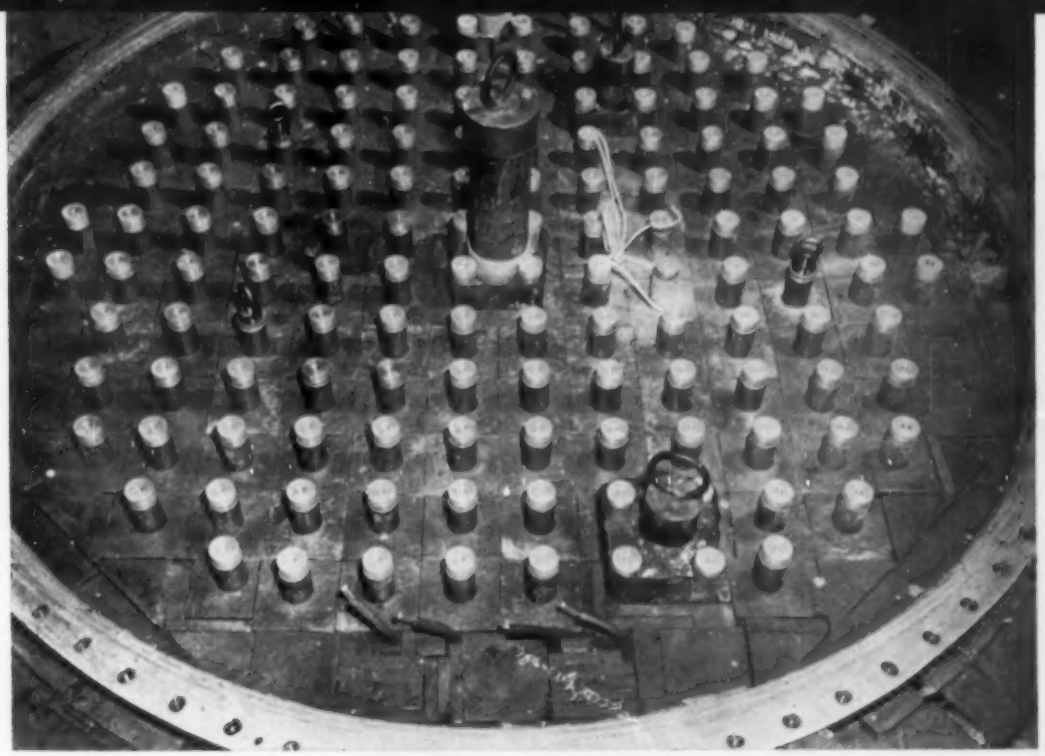

Fig. 2 – Top of Reactor Core of Argonne National Laboratory's Heavy Water Reactor Before Top Shield Was Placed. Ends of round fuel elements (uranium rods) are shown in regular array

behaves similarly to U^{238} in that it does not immediately sustain the chain reaction but has to be converted over a period of time to a new fissionable atom.

When the concentrations of the radioactive fission products, the plutonium, and associated elements build up in the fuel, they change its physical and metallurgical properties and even its shape (if a solid). Periodically these materials either have to be removed or brought back to their optimum concentrations. This usually means chemical or metallurgical processing behind radiation barriers and by remote control – expensive processes obviously part of the fuel cycle. They can also tie up a considerable quantity of costly fissionable materials in the processing operation. For these reasons, the reactor has to be designed so as to keep the number of fuel cycles or replacement operations to a minimum and to keep them as cheap as possible. The reprocessing cost can be considerably offset if the cheaper U^{238} can be burned in a breeder reactor but it must be emphasized that there is a very delicate balance of economic factors involved here.

It should also be pointed out that most of the chemical elements have a certain probability of capturing neutrons and thereby removing neutrons from the chain reaction. Certain common materials of construction or alloying elements have a high probability of capturing neutrons; only very small quantities of them can be tolerated in the reactor. Some of the fission products also act as bad "poisons" for the same reason, and their build-up can determine how frequently the fuel has to be purified. In general, the higher the U^{235} content in the fuel, the greater the flexibility of the design in this regard, and the more of those materials which have moderate or high capture which can be tolerated.

It follows from what has been said above that excess plutonium extracted from one reactor can be used for enriching new reactors, or even in reactors which would consume plutonium alone.* Here again, if this objective is designed into the reactor, the design of the fuel elements will be drastically influenced.

Natural thorium (Th^{232}) in itself is not a fissionable material as used in reactors; however it captures neutrons to form Th^{233}, which decays through an intermediate step with a half-life of about 27.4 days into U^{233} which *is* a fissionable atom. Thus, it is theoretically possible to use an alloy of thorium and U^{235} for a fuel element.

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*Editor's Note – Plutonium metal and its use in reactors will be considered in a four-session conference at ⬤'s National Metal Congress and Exposition in Chicago, Nov. 4 and 5. See program section starting on p. 66 of this issue.

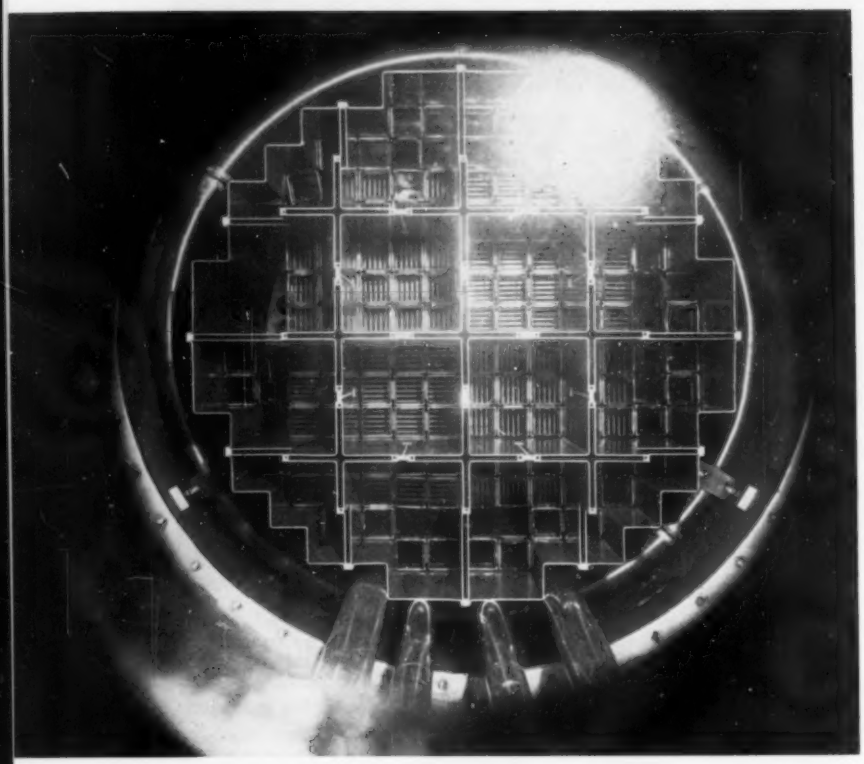


Fig. 3 — Looking Down Into Pressure Vessel of Experimental Boiling Water Reactor Showing Arrangement of Fuel Elements. Each is an assembly of six long plates, accurately spaced to permit circulation of coolant (water). Each plate has a core of uranium alloy, clad in "Zircaloy-2" for resistance to purified water at 600 psi. The uranium alloy contains 5% Zr, 1.5% Cb and 93.5% U enriched to twice its natural content of U^{235}. The reactor produces enough heat to generate 5000 kw. of electricity which is fed into the laboratory's distribution system

If the reactor is designed as a breeder, the U^{235} will maintain the chain reaction until sufficient U^{233} builds up to sustain it and in this way the Th^{232} can be burned. (Either U^{238} or Th^{232} can be used in a "blanket" around the reactor core to capture the neutrons which might otherwise escape; in so doing they produce a certain quantity of fissionable material which can be extracted economically by processes similar to those used with the fuel elements.)

Radiation and Corrosion Effects

When an atom in a fuel element fissions, it liberates a great deal of heat which has to escape through the surface of the fuel element. (This is the heat that is useful in producing electric power, since the only practical way for utilizing nuclear energy now known is to substitute a nuclear reactor for the firebox in a boiler plant.) The heat is removed by a coolant which then goes to a heat exchanger. The center of the fuel element will be much hotter than the surface. Attention must be paid to how well the fuel material conducts heat and (if it is a solid fuel) whether it has any phase transitions which will warp it or change its properties. Another difficulty which has to be foreseen, and the fuel element must be designed so as to prevent its occurrence, is that certain materials disintegrate under radiation. When fission occurs, or radioactive atoms disintegrate, or neutrons are colliding with atoms, the atoms recoil. This may cause some types of microcrystals to grow in one dimension and shrink in another. Such growth can distort the fuel elements and even rupture them, thereby shutting down the reactor. It must be remembered that materials in the reactor core become intensely radioactive and all repair work must be done behind shields and under remote control. Long shutdowns, besides being troublesome and inconvenient, can greatly increase the cost of power.

Uranium, thorium and many of their alloys are very active metals, particularly when hot. They can react with the coolant solutions or with neighboring substances. For this reason many fuel elements are "canned" with some material which will prevent fission products from getting into the coolant stream where they would build up a lasting radioactivity in that part of the system, its piping, pumps, heat interchangers and so on. This canning or coating material

must also be of such a nature that it does not absorb too many neutrons. Further, the heat must pass through the thin coating and since the amount of heat which has to be removed per square inch of area is very large, its thermal conductivity must be excellent. This frequently requires a metallurgical bond between can and fuel. The higher the energy at which the power reactor is to be operated, the better the heat conduction has to be and the more formidable the problem. It might be solved for low-energy power reactors just by having a tightly fitted can, but high-energy reactors require special means of getting the heat *from* the fuel element *through* the can *to* the coolant.

Some fuel element alloys will not be attacked by the coolant to be used. New problems then arise because the coolant stream and handling equipment as well as the interchanger will become intensely and permanently radioactive from the fast recoils. Any work on this system would have to be done by remote control. Further, the materials used in making the fuel element noncorrosive greatly increase the difficulties in the chemical reprocessing. (This is true also for the materials used for the cans or the bonding alloys.)

It is obvious from the above statements that the geometry of the fuel elements can play a very decisive role in how the heat is removed from the element.

In homogeneous reactors (where the fissionable atoms are held in solution, as a fine suspension, or as a liquid alloy) many of the problems such as shape stability, radiation damage, and large inventories in fuel reprocessing cycle are minimized, but new ones appear. Corrosion of the pipes conducting the fluid is greatly enhanced. The problem of mass transport – where the fuel fluid dissolves materials at the hotter parts of the reactor and deposits them in the colder parts – can become very troublesome. If aqueous solutions are used, the gas generated by the radiation has to be disposed of.

The above listing of factors to be considered in designing a fuel element is not meant to be exhaustive but rather points to a greater complexity of the problem. It sharply points out that anything done to the fuel element can decidedly affect the design of the reactor. This is true even for changes which occur in the fuel processing outside the reactor. If all the uranium or thorium is to be consumed, the outside operations will have to be performed many times; even in many of the advanced designs not more than a few per cent of the available fuel is consumed before purification is necessary.

The Future Reactor

It is clear that if power reactors are to be designed which produce cheaper and cheaper power, not only the reactor engineers and economists but the chemists, physicists, metallurgists, chemical, mechanical and electrical engineers will have to join forces. What each man can do in his area is profoundly influenced by what the other men do in their areas, and compromises will have to be made to arrive at the minimum cost. The compromises which may be the best today will not be the optimal ones in the next generation of reactors.

At present our background information in high-temperature materials is inadequate to design reactors to operate as hot as we would like and thereby produce steam of sufficient temperature and pressure to take advantage of our present state of development in power engineering. As this background information accumulates, reactors will be designed to operate at higher and higher temperatures. Also, as the atomic power industry develops, the ratio of cost of fissionable materials to source materials will change for the better, and this will result in reactors with more highly enriched fuel elements. As more reactors are built, their necessary special materials which are now very expensive will become cheaper and can be used more extensively.

Inasmuch as the design of the fuel element is so intimately tied up with the design of the reactor, it is clear that for some time to come the design of the fuel element is almost sure to be different for each generation of reactors. A great deal of the present cost of producing power is determined by the type of fuel element used, and the way this affects the costs of the fuel cycles, the design of the reactor, and the necessary inventory. Hence, it is in this area that the greatest progress can be made in reducing the costs of atomic power.

The author feels that the future power reactor will have to be one in which the fuel assemblies are simple, the chemical processing minimal, and one in which the reactors operate at high enough temperatures to take full advantage of the thermodynamic efficiencies which the power engineers have now achieved in the production of electricity by steam turbines. This, he feels confident, can be achieved – but it will require much development work on the part of many workers.

Our Grandchildren–More Power to Them*

WHAT WILL the atom mean to our grandchildren? Assuming that no country will be fool enough to start a shooting war, the atom is their hope!

Bearing in mind the expansion of population and fantastic increase in the use of power, our best experts predict that our supply of fossil fuels (coal, oil and natural gas) will be exhausted in from several decades to less than 200 years, depending on our ability to conserve them. The need for new sources of power is pressing. Without question, the answer lies in power from the fissionable atom (uranium and plutonium), from fusion of the heavy hydrogen in water, and from solar energy. The two latter are in the more distant future; the nuclear power plants will have to provide the bridge over the gap.

Nuclear power is already being generated. Free Europe anticipates 15,000,000 kilowatts of electricity by 1967 from this source. For an infant the reactor isn't doing badly – compare the output of the power houses at Hoover Dam: 1,250,000 kw.!

Remember that a nuclear reactor is simply an atomic bomb going off very slowly. It produces the same waste fission products. So for a moment here I would like to digress and return from reactors to "fallout". To get an idea of the quantity of fission products which must be safely disposed of, a reactor producing 25,000 kw. of electricity for a year will produce about the same quantity of radioactive waste materials as a 1-megaton bomb. Since it has been estimated that all the bombs detonated to date, largely over a four-year period, have contributed to our atmosphere and stratosphere something like 50 megatons, this same amount of fission product would be generated in Europe's anticipated electrical capacity in 1967 in about a month.

It is true that most of the waste products of a reactor are not blown up into the air but contained in one of several different ways. But sooner or later they must be disposed of somewhere and somehow. Thus the topic hooks up with that of "fallout", which has been of much public interest. Statesmen of various countries have been heard from, and we have had condemnatory expressions from a host of well-intentioned but poorly informed people, many of them eminent scientists in their own fields. This includes Dr. Albert Schweitzer, for whom, as a physician and as a lover of music, my respect borders on veneration. Yet I wish he hadn't written that letter – he was guilty of the scientific sin of failing to verify and evaluate his references.

There seem to be two basic misconceptions floating around. One is that the U.S. Atomic Energy Commission is holding vital information pertinent to the public well-being under the veil of "security". This I can state categorically is not so. I have seen most of the classified documents on the subject, and I know that essentially the only information which has not been released in an unclassified form is material which has no bearing on the health aspects.

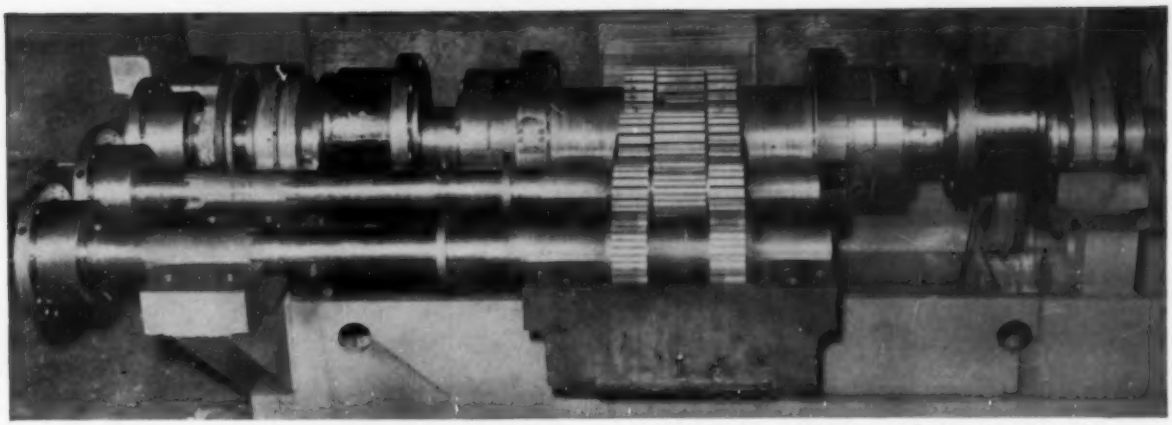
The second misconception is the implication that the Atomic Energy Commission and the Department of Defense have been willing to play fast and loose with the health and safety of the public at large. Having been in charge of radiologic safety at two test operations in Nevada, and having a finger in the pie of all tests, both in Nevada and at Eniwetok since 1951, *and* having six children, I think I am in a fairly good position to answer this one: We used the best scientific brains available. Not every decision was correct, but I cannot feel that anything which was done jeopardized your grandchildren or mine or anybody else's.

Could it not be that these self-appointed Messiahs, who are crying that the current test programs presage the end of the race, are keeping their eyes on the *wrong* ball? I claim that the present test programs constitute a large-scale tracer experiment. It might be nice to have done it some other way, but this is the way things have worked out. The problem is to protect the future. Today we are gathering the data which will tell us whether or not our dreams for the future will bear sweet fruit or bitter, whether or not man himself will be the limiting factor to our ultimate progress. Stopping weapons tests will not stop production of harmful radioactive waste products in power reactors.

It is quite possible that the medical and biological aspects of atomic *power* may be the factors which will determine the rate at which progress can be made. I also believe that none of our problems are insoluble, even though final solutions will require time and money and effort.

Nowhere within the Atomic Energy Commission have I ever encountered a lack of patience or an unwillingness to accept either expense or delay in order to assure health and safety. I believe that the power problems of our future are in pretty safe hands unless someone either from malice or stupidity decides to rock the boat. I urge your confidence in those who are striving to see *all* of our grandchildren enter into a brighter new era, and do it safely. Yes, more power to them, atomic power, thermonuclear power, solar power! I have the feeling that their grandparents are striving honestly to get them off to a good start.

*Verbatim extracts from remarks by Thomas L. Shipman, M.D., health division leader, Los Alamos Scientific Laboratory, before New Mexico Bankers Assoc., May 25, 1957.



Assembled main shear shaft and front gate drive shaft used in model 541 guillotine flying shear. Shafts range up to 9¼" in diameter and 16' in length. All shafts are fabricated of type 4340 nickel alloy steel.

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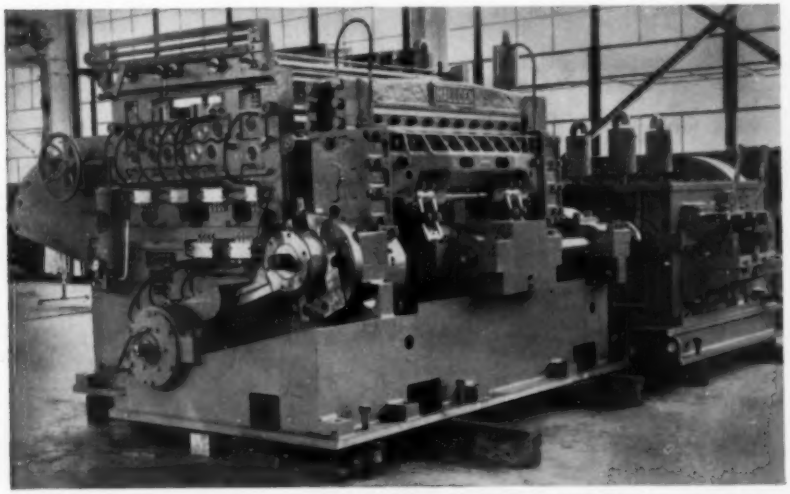

Hallden guillotine flying shear. Nickel-chrome-moly steel, heat treated to a nominal hardness of 260 Brinell and tensile strength of 125,000 pounds per square inch provides the properties needed for heavy-duty shafting in shearing machines. Built by The Hallden Machine Co., Thomaston, Conn.

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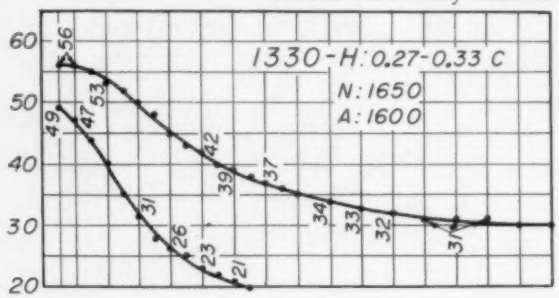
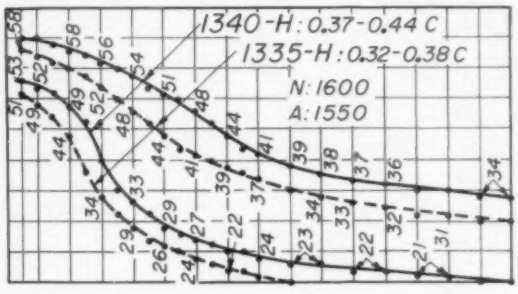
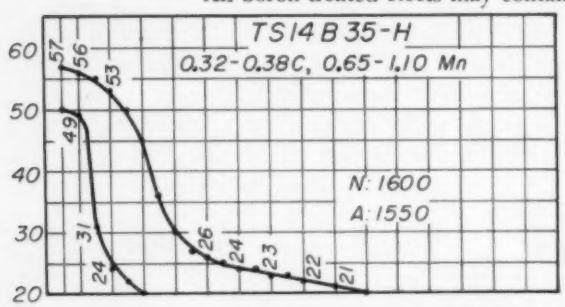
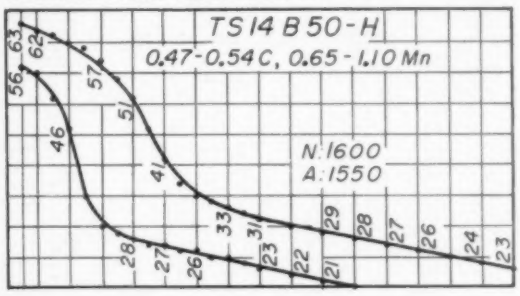


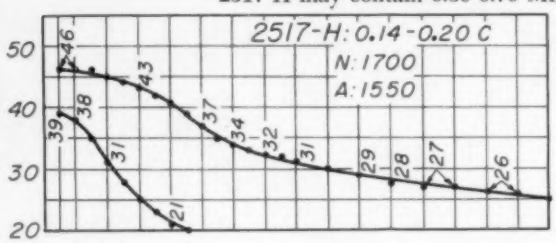


All boron-treated steels may contain 0.20-0.35 Si and 0.0005 min. B

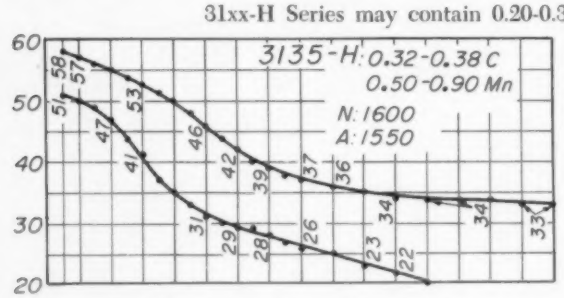


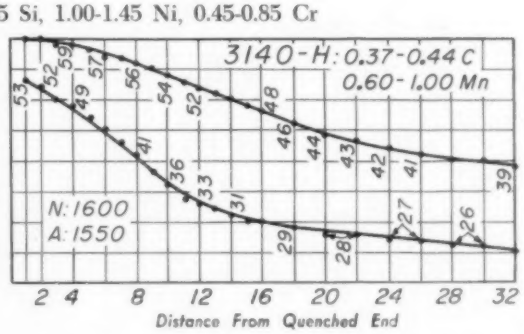


2517-H may contain 0.30-0.70 Mn, 0.20-0.35 Si, and 4.70-5.30 Ni

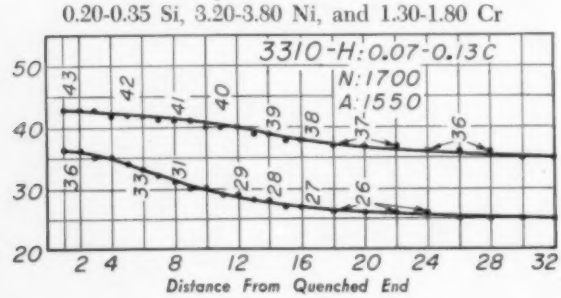


31xx-H Series may contain 0.20-0.35 Si, 1.00-1.45 Ni, 0.45-0.85 Cr





3310-H may contain 0.30-0.70 Mn,
0.20-0.35 Si, 3.20-3.80 Ni, and 1.30-1.80 Cr



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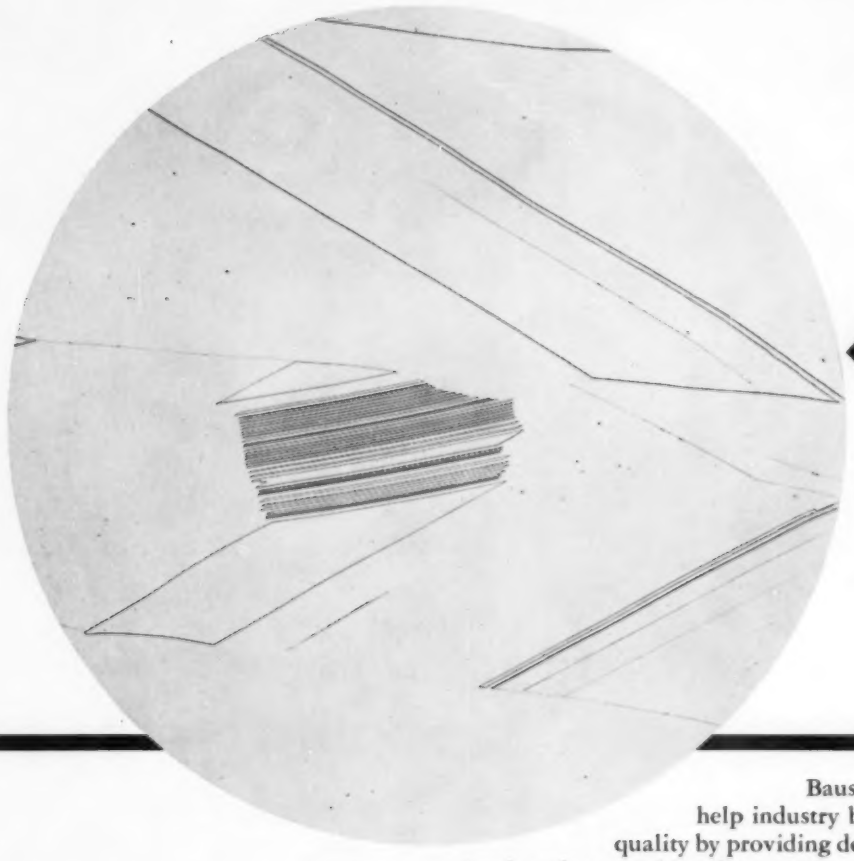

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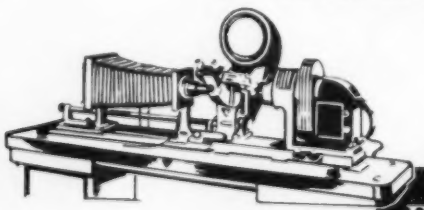

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The Future of High-Temperature Metallurgy

*By L. P. JAHNKE**

Future advances must be conceivable, feasible and desirable. On this basis the author considers the effect of purity (both chemical and structural), especially of alloys based on columbium, molybdenum or tungsten, and predicts that by A. D. 2000 we will have alloys of useful strength up to 5500° F. (Q27a, 2-12; SGA-h)

FORECASTING the relative position of humanity and a technology merely 10 to 20 years hence is not too difficult. One merely assumes that the projects now entering the development laboratory will be successful. But trying to project this technology an additional 30 years is more hazardous by several orders of magnitude. New ideas, uncovered only yesterday in those few places where basic research is truly allowed, must be comprehended and their impact on practical metallurgy extrapolated. This requires imagination and wisdom beyond possibility. The difficulty is compounded, since new concepts spring into existence from the pressures of such unpredictable forces. Only a few glimpses of vistas in the far future are seen by men of rare ability, and these are far too fleeting to form a scene.

Nevertheless, a speculation about the future of high-temperature metallurgy is enjoyable — particularly now when humanity is so certain that anything which can be expressed is soon forthcoming from the scientist's laboratories. This is not true, of course. There are limits, and prophesying can be at least partly useful and still enjoyable only if the prophet sufficiently qualifies his remarks. For instance, the things which certainly may be accomplished must satisfy three requirements: First, man is now able to imagine them. Second, they do not contradict any of the laws of nature which man now perceives. Third, a motivation exists for their practical accomplishment. In brief, the advances must be conceivable, feasible, and desirable.

These are necessary qualifications but they only apply to the point of time when the prophecy is being made. What makes so many old prophecies so ridiculous is the fluctuation in man's ability to imagine, in his understanding of nature's laws, and in his ability to justify his efforts. Of the three factors, perhaps the most

*Manager of Metallurgical Engineering, Applied Research Operation, Aircraft Gas Turbine Div., General Electric Co., Cincinnati, Ohio.

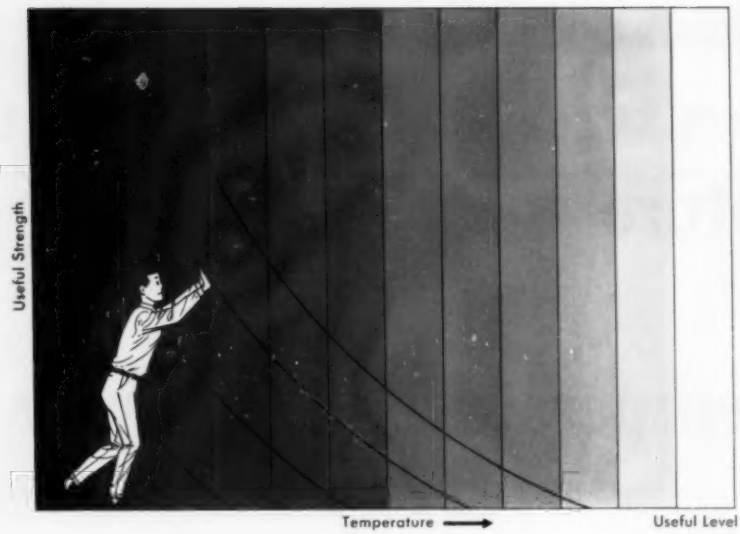


Fig. 1 – As the Temperature Front is Raised, Strength Must Also Be Improved

important and the least heeded is the necessity to understand the physical laws which we already have tentatively established. Imagining impossible things is dangerous because it is so easy; it is most important to recognize the limits beyond which truly monumental difficulties exist. It is also important to be sure the limits we see are true limits.

The knowledge of these probable limits is supposed to be learned by us in our universities. Unfortunately, the hard-won fundamental knowledge is often treated, if at all, with frightening glibness, with the result that many earnest and capable technologists are frustrated by spending their lives fighting opposing rules of the universe. There is, of course, a danger in the tacit acceptance of existing limits, but there is no substitute for understanding why other men have believed that these limits exist.

With this as background and general ground rules we should try to peer as far ahead as we can, but later be unafraid to ignore or be amazed at our misconceptions. In this essay we are concerned with high-temperature metallurgy and its potentialities. The motivating force for advance exists and evidently will continue to exist from our efforts to improve power-producing equipment of all types. The most probable

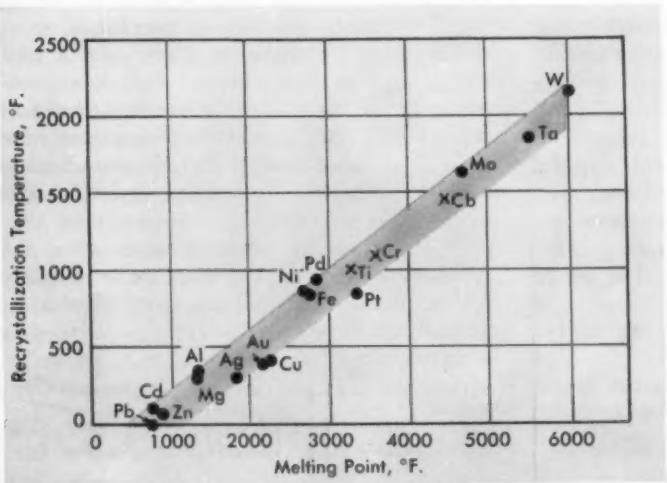
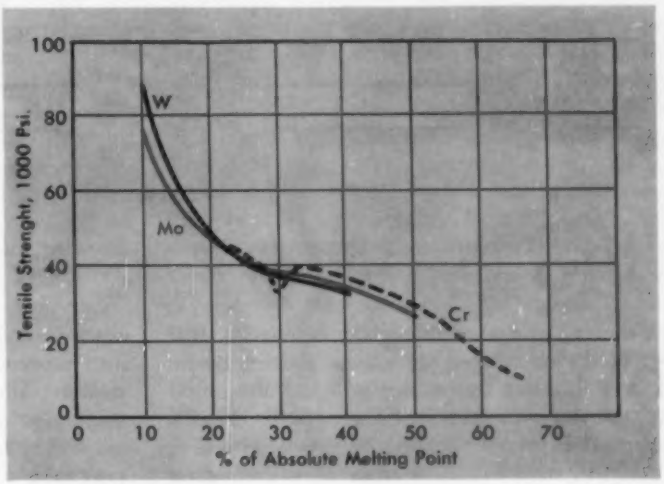


Fig. 2 – Recrystallization Temperatures of Cold Worked Pure Metals Are Proportional to Their Melting Points and Are Roughly Equal to the Temperature of Rapid Creep Under Stress

Fig. 3 – Short-Time High-Temperature Tensile Strength of Refractory Metals (Unalloyed) Is About the Same at the Same Fraction of the Absolute Melting Point



directions of our efforts will be toward useful strength at ever higher temperatures and toward less variable and more reliable metals. For our present purposes we can disregard such difficult problems as the depletion of ore resources and the high cost of certain desirable metals. We also will think only of the advancing front of temperature, although it is realized that improvements in strength must be made as temperature limits rise, as sketched in Fig. 1.

Present Status – Figure 1 will help to show where we are now. (In our rapidly moving technology, as in an airplane, it is difficult to fix your location.) Where we are, in degrees Fahrenheit and useful strength, naturally depends on our base-metal system. "Useful strength" is here defined as the ability to sustain 10,000 psi. for 100 hr. without fracture, and the table below at left indicates that in the 20 to 25 years of fairly constant effort on high-temperature metals, the best we have done is to obtain useful strength up to 75 to 80% of the absolute melting point.

Base Metal	Melting Point	Useful Strength* at	Percentage†
Magnesium	1200° F.	650° F.	67
Aluminum (conventional alloys)	1200	650	67
Sintered aluminum powder	1200	900	82
Titanium	3020	1200	48
Iron (martensitic alloys)	2800	1350	56
Iron (austenitic alloys)	2800	1600	63
Nickel	2650	2000	79
Cobalt	2720	2000	77
Columbium	4400	2450	60
Molybdenum	4760	2700	60
Tungsten	6170	2600	46

*10,000 psi. for 100 hr.

†Figured on absolute temperature; that is, temperature for useful strength plus 460 divided by melting point plus 460.

The results outlined in the table below have been accomplished by truly remarkable work, almost all of an intuitive nature. While useful mechanical analogies of the process of hardening of metals were devised at least 40 years ago, no *basic* understanding of what caused strengthening has existed and only glimmerings now exist. We do have many empirical rules with which we can make rapid progress in new systems, but it is generally agreed that useful strengths at absolute temperatures above 80% of the base element's absolute melting point will be very difficult to attain. There are, however, at least two possibilities which, if successful, could raise this limit to 90 and even 95%. These will be discussed later. One was used already in SAP (sintered aluminum powder) which the table shows has pushed its figure in the last column up to 82%.

Present Limitations – When considering the high-temperature possibilities of a pure metal, the first limitation is the recrystallization temperature of the highly cold worked metal. This is where the thermal energy of the atoms is sufficient to allow appreciable movement. If the metal is stressed under these conditions, creep is also rapid and rupture follows. Figure

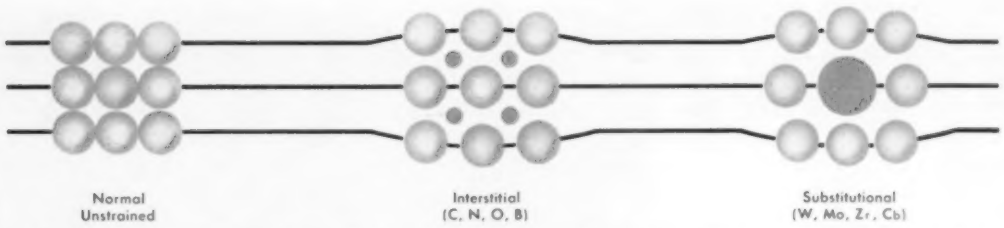


Fig. 4 — Two Methods of Strengthening Metals by Increasing Interatomic Strain, Either by Inserting Atoms Within the Lattice or by Substituting Other Atoms of Different "Size"

2 shows the remarkably good correlation that exists between melting points and minimum recrystallization temperatures. Thus, the useful temperature limit of a fairly pure metallic element is roughly defined by this band and is generally from 35 to 45% of the absolute melting point. A corroborative finding is that the short-time tensile strengths of pure metals are very nearly the same at the same percentage of the metal's absolute melting point, as shown in Fig. 3.

These data fairly well define the limitations of unalloyed metals for high-temperature strength. We are most heavily restricted by melting points, which are measures of the forces which maintain the atoms within their lattice locations.

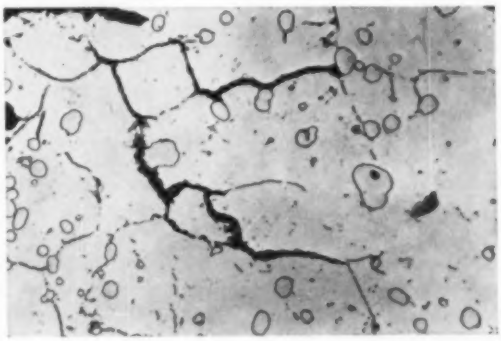
I have gathered some information about the development time it takes to push the maximum temperature for strength from the 35 to 45% of melting point for a pure metal up to the 70 to 80% level by any means whatever for alloys based on that metal. Generally, in 12 to 15 years we will have progressed nearly as far as we will go. The following 5 to 10 years yield small but always important gains. Systems based on the various metals provide varying resistance to being pushed up in this way. Some start slowly and seldom reach their full potential. Others are more rapid, due to the metallurgist's good fortune or to the largesse of nature.

We are nearly at the limit for aluminum, nickel and cobalt. Their temperature increases occurred at about an average rate. Iron alloys (useful strength up to 56 to 63% of melting point, absolute) were surpassed by nickel and cobalt, and never have reached a high level; iron alloys represented a tougher problem and success with the nickel and cobalt systems relieved the existing motivations. Columbium and molybdenum have started fast due to the background of empirical rules for alloy development derived from work on nickel and cobalt. Tungsten has really just begun its development but should also proceed quite fast. Titanium is strongly resisting efforts to advance its temperature of usefulness.

I will not presume to discuss in any detail the principles used in alloy development. Briefly, as shown in Fig. 4, we dilute the base metal with different sized atoms which tend to increase the lattice strain. Or, as in Fig. 5, we arrange for the dispersion of fine, hard particles which restrict the movement of dislocations and thus of grain boundaries. Often we alloy for oxidation resistance, or for grain size refinement. Eventually, we do all of these simultaneously, and by doing so successfully we move up the temperature for useful strength (10,000 psi. for 100 hr. safety) from 40 to perhaps 80% of the melting point in absolute temperatures.

The boost in aluminum shown in our table at the outset from 67% (second line) to 82% (third line) was attained with a new concept which may be good for boosts in all base systems — even to 90%. This unfortunate symbol SAP stands for "sintered aluminum powder" which has its remarkable high-temperature strength

Fig. 5 — Method of Strengthening Alloys by Precipitating a Dispersion of Fine, Hard Particles in the Main Crystals



because fine, insoluble particles of Al_2O_3 are cleverly dispersed throughout the structure. In most other systems, the particles we have inserted in one way or another either dissolve or agglomerate at high temperatures, and their strengthening value is lost. But if the *insoluble* particles are fine enough and have proper coherency with the basic lattice structure, the possibility of an additional 10% (of melting point) should be attainable in any system. Such efforts are proceeding now in many laboratories and offer one of the hopes for important future advances.

Perfect Structures – There is another possibility, more long-range and surely more "dramatic" (if the Editor will permit the cliche) which may give useful strengths practically to the melting point itself. It was mentioned that easy movement of dislocations and high-temperature weakness go hand in hand and that we could resist these movements with some success by adding different sized atoms and fine, insoluble particles. But if the dislocations can be entirely eliminated, truly remarkable strengths are attainable at low temperatures as well as at high temperatures.

This is not altogether hypothetical, for metallurgists in several laboratories have successfully grown tiny, single-crystal "whiskers" of many metals which are free from damaging dislocations and imperfections. These whiskers grow in one direction only. They generally form by metal deposition from a gaseous phase (such as halide reductions and distillations).

One series of tests on pure copper whiskers (0.0025 mm. diameter) showed yield strengths in excess of 50,000 psi. This is at least six times the yield strength of commercial copper. Similarly, tensile strengths of 2,000,000 psi. have been measured on iron whiskers.

The fibers have other remarkable properties: If bent and reheated, they return precisely to their original shape. "Whiskers" are nearly perfect crystals both in purity of material and purity of structure. This is what nature intends us to have, and the imperfections in normal metals are there as a monumental challenge. Here is another glimpse into the future.

Purity – The perfection of these metallic hairs leads to comments on improvements in alloy melting and processing. In the past five years, we have been melting nearly all high-temperature alloys in vacuum. These are imperfect vacuums at best, but they allow a vast improvement over the same nominal alloy melted in air. We have achieved a new order of magnitude in purity. We can exclude most of the elements (especially gaseous) which we don't want and more carefully control the amounts of those we do want. Thus, we achieve benefits in strength and benefits toward the other desirable goal, namely, reproducibility.

In fact, reactive metals such as titanium, molybdenum, columbium, chromium and tungsten simply cannot be melted in air because they react with oxygen and nitrogen so violently. The metals must of course be protected from oxygen and nitrogen when hot. This is a major problem in some applications and is beyond the scope of this article. Present vacuum melting follows two general methods – induction and arc. Induction melting allows long times for the vacuum to suck volatiles from the molten bath, but this increases the possibility of contamination by refractories in the furnace. Arc melting generally results in purer materials, for the metal usually comes from consumable electrodes and accumulates in water-cooled copper molds. Solidification is rapid and metal temperatures in the arc are very high.

There are yet better purification methods than these. Zone melting, already in use in the production of the superpure metals required by the electronic industry, "floats out" the impurity elements by moving a molten band of metal slowly along a bar again and again. Another is levitation melting, where the metal is held in evacuated space by a high magnetic field in contact with nothing, and is melted there by induced electric currents. This method can now be used for tiny amounts of metals. The adaptation of these processes to larger quantitiy production will be difficult, but possible in coming years. A yet more recent vacuum melting technique is electron-bombardment melting which uses the same principle involved in X-ray tubes. The "target" becomes the metal to be melted. Very excellent vacuums are necessary and a remarkable degree of purification seems possible.

All of these methods increase purity of composition, or at least allow us to achieve controlled purity, and thus higher reproducibility in the alloys. Methods to achieve purity of structure in *large* pieces, as we now do in the tiny whiskers, are not available and seem to be at least several decades away.

For the reactive elements (Ti, W, Cr, Mo, Cb) which require vacuum melting*, further process-

* See article by W. E. Jones, p. 133, this issue.

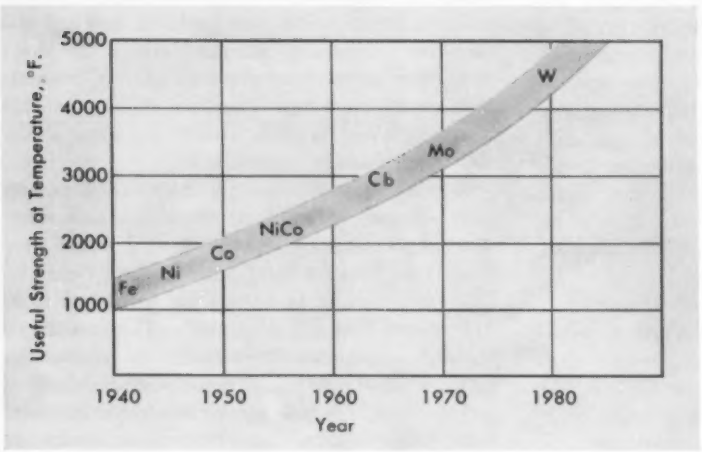


Fig. 6 – Prediction of Future Possibilities in High-Temperature Metallic Alloys

ing into desired shapes should also be done in controlled, inert atmospheres. Already one of the alloy producers is constructing a large room from which air will be excluded, in which these alloys can be forged by remote control without danger of gas absorption or oxidation.

The Prognostication – With these things we approach the place where we can make a reasonably sure prognostication. We have ahead of us the development of columbium, molybdenum, and tungsten alloys, the increasing use of melting and processing methods which tend toward greater perfection in control of purity, and the addition of controlled amounts and sizes of stable (insoluble) strengthening particles.

If we combine all these, what are the expectations, not only as to date but as to temperatures at which useful strengths will be available? Figure 6 presents this prediction.

Presuming that our rules of alloy development allow us to attain useful strength at temperatures up to 80% of the melting point, it appears that we could be near to the end of these possibilities by 1980 or 1985. If stable phase additions are successful, we can add another 10% to the height of the curve. If perfect crystals can be obtained and used, an additional 5% may be available (plus extreme strengths at lower temperatures). If most of these ideas are successful, it is quite possible to have useful strength close to the melting point of tungsten, say 5500° F. Even with the best of luck, this will occupy us through the readers' useful careers, or probably up to the year A. D. 2000.

Of course we cannot stop here; ever higher temperatures will be required. The limit we now see is simply related to the melting point of tungsten, whether it be 80% or 99% of it. The tools and knowledge to attain this are nearly all within our grasp. The problem for the 21st Century may well be to increase the melting points by tricks of physics which we can scarcely imagine now. There is, however, at least one evident possibility:

You may have read about the use of extremely high temperatures and pressures to make artificial diamonds. This same technique has produced a new crystalline structure of boron nitride which is as hard as diamond and many times as hard as nature normally makes boron nitride. Applied to metals, these techniques could possibly do what we want – increase their melting points by achieving a new stable lattice structure in which the atom bonds are stronger than the ones we now know about.

The limit of this concept, which – even if possible – must surely be hundreds of years away, would be to force the atomic nuclei very close together. This state exists in certain stars. If such were accomplished, not only would melting points practically cease to exist, but densities would be fantastically high.

Thus, the pathway is reasonably clear for 25 years, but becomes progressively more cloudy beyond that. With men of sound fundamental training, allowed freely to inquire about fundamental truths, clearer visions will come. With men to grasp these visions and transmit them, imaginatively, into things of value to humanity, progress will be certain. There are places for men of both types in this most important and exciting field of science.

Book Review . . .

A Survey of American Foundry Practices

*Reviewed by GEORGE F. WATSON**

PRINCIPLES OF METAL CASTING, by Richard W. Heine and Philip C. Rosenthal, McGraw-Hill Book Co., New York, 1955. 639 p. $7.50.

THE FOUNDRY INDUSTRY in its varied complexity does not lend itself readily to a thorough discussion within the confines of one book. Each of the problems of pattern making, sand control, melting practice, metallurgy and mechanization deserves a complete volume without undue elaboration of the text. In fact, there is sufficient material for additional volumes on foundry practice for each of the major divisions: the light alloys, the copper-base metals, cast irons and steel.

Mr. Heine and Mr. Rosenthal have endeavored to survey the entire foundry field in 627 pages of text ranging from molding machines and mechanization to the theoretical treatment of solidification, feeding of metals and metallurgy of steels and gray iron.

According to the preface, this work is designed and written as a text for college foundry work in two different courses at the beginning level. One course is for metallurgical engineers who need the theoretical approach, and one is for mechanical engineering students who must become familiar with the properties and the limitations of castings.

For the beginning student in either of these courses, this book is admirably suited. It not only describes the various processes in some detail, but has complete and up-to-date references for further study at the end of each chapter. There are, for example, 44 references on gray iron foundry practice, and 33 on gray iron metallurgy. These references are limited mostly to articles in A.F.S. *Transactions* and *Foundry* magazine.

The equipment used in the modern foundry is thoroughly discussed and many pictures and diagrams are included. Molding machines of various types, core blowers, melting equipment, sand testing and even cleaning and inspection are covered. However, this text should not be considered a reference book for the operating foundryman, since it cannot be used to solve difficult problems in the foundry. But it can be of value to a foundryman as review of many new things that have appeared in the literature since World War II. For instance the two chapters "Solidification of Metals" and Pouring and Feeding Castings" could be read with appreciation by most practical operating foundrymen. It may be impractical to write one book that bears the same relation to the foundryman that Metals Handbook does to the metallurgist. "Principles of Metal Casting" does as well in this respect as could be expected of one text.

It is hard to criticize a volume that has covered so much ground in a large and complex subject so well, but it would appear that some subjects could have been left out so as to strengthen other more vital subjects. Molding equipment and mechanization are discussed in about 30 pages of text that could tell the student little about why each molding machine has a definite place in production and what it is. Possibly the mechanical engineering students would gain something from this chapter, but it would seem that this space could have been used to elaborate more fully upon more fundamental considerations.

Molding and core sands are adequately treated in two chapters although more emphasis might have been warranted. Methods for testing sands are described at some length, but too little is said about what the tests mean. The molding sand defects that plague foundrymen such as scabs and buckles, are mentioned on only three pages and those due to core sands, such as blows, are not discussed at all.

The book is a valuable addition to our growing library of foundry literature. Many high school students at the advanced level and many students at the beginning level in college should find it a valuable textbook.

*Ceramic Engineer, Research Center, American Brake Shoe Co., Mahwah, N.J.

Why Be a Metallurgist?

An interchange of letters relating to the green insert in July *Metal Progress*.

Los Angeles, Calif.

To the Editor of Metal Progress:

I will be a senior in West Los Angeles High School next year. I get good grades, especially in math and science. Last week, one of our neighbors talked with me about going to college to learn to be a metallurgist. He left me your magazine and asked me to read the part about how much we need metallurgists in this country.

I saw our neighbor yesterday and he answered a lot of the questions I had about what sort of work metallurgists do. Some of my questions, though, he said he didn't know the answers to and maybe I should write to you. These are the economics kind of questions. You see, we had some economics in our Social Studies in school, and my Dad (he teaches it in the University), helped me understand some of it real good. You know, about supply and demand and how they make prices go up or down, how markets work, why prices reflect the values people put on things, etc.

From your magazine, I learn I can make $2.20 to $2.70 an hour if I go to college for four years and become a metallurgist. This seems funny to me because I'm now getting $2.10 an hour running a drill press at Douglas Aircraft during school vacation. It only took me a month to learn how, and I got paid while I learned. Some of my friends' Dads work as an electrician and a carpenter. They get $3.90 to $4.50 an hour. I read in the paper where plasterers and hod carriers are being raised here to $4.50 an hour. They don't have to go to college.

In Social Studies we learned that the price for anything represents both the cost for making it and the demand, or how much people value it in dollars. It seems to cost more to become a metallurgist than an electrician, yet the price of electricians is higher. My question, then, doesn't this mean we need electricians more than metallurgists? My friend's Dad says electricians aren't looking for more people to learn to be electricians. He says if there were more, they wouldn't make so much. Our teacher explained that when the supply of anything increases, the price drops in the market. You know, like when chickens lay lots of eggs they are cheaper. It seems kind of funny to me to have a Society for metallurgists wanting more of them when people don't seem to want them so much and when more would lower their price.

Maybe it's just because a college teacher wrote all that about needing metallurgists. I'll bet that college teachers need lots of people going to college because if so many people don't go to take metallurgy, people who teach metallurgy might have to pump gas or something.

Maybe your magazine is for companies in the metal business. It looks awful pretty and expensive for metallurgists to buy if they are not very rich. I can understand, too, how companies in the metal business will want more metallurgists so they won't cost so much. My Dad's economics magazines look scroggy – no ads except for books. They don't talk about needing more economists, although if they had more to buy the magazines they could be prettier, too.

My Dad should write something about economics for your magazine. My neighbor who is a metallurgist says he never had any Social Studies in school like I did. He says now he wishes he had.

Allen Alchian

The Editor's Reply

CLEVELAND

Dear Mr. Alchian:

Your very interesting letter of July 30 has arrived. Its theme is primarily economics – dollars and cents – so let us stick to that level for the first part of my reply.

You compare your hourly wages of $2.10 as drill press operator requiring a month's training with wages of $2.20 to $2.70 for four-year engineering graduates. I wonder if you realize that these are *starting* wages. I do not know what machine operator's wages in the Los Angeles region are after 20 years' experience, but I imagine they cannot be higher than the $3.90 to $4.50 you quote for your friends' fathers who are electricians and carpenters. For a 40-hr. week and 2000-hr. year (assuming full employment) this means $7800 to $9000 per year, and they are ceiling wages, wages fixed by the union contracts and not by the man's ability. Even so these wages may look pretty good when you compare them with the results of a recent study by Engineers' Joint Council of salaries of 108,000 engineers, which shows that *average* salaries of all engineers 20 years after graduation is $10,000. However, the upper quartile is $12,000 and is still on the up-grade. This means that one quarter of all engineers get *more* than $12,000 per year after 20 years of experience, and that their salaries get *still higher* as their experience increases.

(A recently completed survey of incomes of members of the American Society for Metals shows that "metallurgists" and "metallurgical engineers" with 20 years' experience have an *average* salary of $12,603 – $2600 *more* than engineers as a group – that the salaries continue upward with extended experience, and that the highest salary reported for a metallurgist with 20 years' experience is $46,000.)

On the basis of these figures – the economics of it – you can conclude that if you are good enough to be in the top quarter of your group (and your thoughtful letter shows that in all likelihood you are) you will be a little behind a machinist or any other artisan for the first few years of your working life but will steadily move on ahead of him as the years go by. Furthermore, if you are real good and have good luck, you can far outdistance the trades unionist in dollars and cents – unless he gets into a situation like Dave Beck's.

So much for the economics of the situation.

Now for some intangibles:

If you are content to become a part of a machine, by all means stay with the drill press. But are you sure you will be satisfied with that very long? If you are content to work on routine jobs, as the boss directs, become a plumber or a plasterer. But are you sure the plumber's life is for you? If your imagination is fired by Los Angeles' free-way system and interchanges, by a jet engine or aircraft, by an earth satellite, a nuclear reactor, by a telephone, television or communications system, by automatic machinery – then by all means become an engineer. You will find that the field of engineering is expanding at almost an explosive rate, that the only limits of your personal and professional development will be set by your own mental capacity and personality. You will before too long get to a point where the salary problem is so minor you will forget all about it.

But that's only if you're good, *really good!* If you're a second rater, forget about it. You'll be happy as a plasterer.

E. E. THUM

P.S. I forgot to answer some of your implied questions. The green insert was not written by a college professor looking for more students. It was written by me, and reflects my life-long impression that American industry could absorb more college-trained men in metallurgy than are being graduated. Most men now serving as metallurgists and metallurgical engineers graduated in other branches (such as civil, mechanical, electrical, chemical) and got their metallurgy on the job and from their membership in the American Society for Metals. This impression is borne out by some statistics: The American Society for Metals (whose members are interested in production and fabrication of high-grade metals and alloys, and equipment for such work) now has a membership of 28,250 and is growing at the rate of 1300 a year, yet only 600 to 650 metallurgical degrees are given each year in all the universities of the United States and Canada.

Thank you for your appraisal of *Metal Progress* as a good-looking magazine. It also makes money. (There's economics again!) The money comes from advertising. The advertisers spend this money because they are convinced that the readers of *Metal Progress* (who are the members of the American Society for Metals) have strong influence on the purchase of the products they advertise. It's as simple as that! E.E.T.

(Another reply to Mr. Alchian appears on p. 146)

What's in the Literature?

*By FRANK T. SISCO**

Searching of metallurgical literature is now so costly in time of high-grade men that it is frequently cheaper to get a direct answer by laboratory research than to find out whether someone else has recorded his findings. It is hoped that machine searching of metallurgical literature will correct this situation, at least in the field of metals engineering. (A14e)

WEBSTER defines "literature", in one sense, as "the body of writings having to do with a given subject". A much used synonym is "documentation", and by the same authority, a document is "any instrument whether written or printed that will convey information", and documentation is the "use of documents".

In engineering and research, this definition of documentation should be amended to read "the use of documents – if you can find them". To the engineer or the scientist documents are technical reports, published technical papers, patents, or technical books in the field of his special interest.

All over the world a tremendous amount of research is being done with the expenditure of very large amounts of money. This research is generally written up, when the project is completed, as a report or as the manuscript for a technical paper. The memory of the average human being is very far from perfect. Consequently, when the average research man writes his report or prepares his technical paper, he hopes that three or five years later he can locate that document to find out what he has done.

Equally important, or even more important, he also hopes that he can find out what others have done in his own particular field. The chances, however, are slim. In 1952 the Library of Congress received nearly 40,000 scientific and technical journals and other serial publications which contained approximately 1,500,000 papers. This is a very large amount of material indeed, applying only to engineering and science.

The effective use of a document of any kind depends on being able to locate it and discover what is in it. This can readily be done for engineering and scientific books. A modern library has its books excellently indexed and classified; if it is an efficient library, the staff can promptly supply a reader with almost any book in the collection. For periodical literature this capability does not exist.

Many years ago, engineers and scientists found that it was an arduous chore for an individual to read all of the available documents in his own field, let alone in adjacent fields of interest, so abstracting was devised to enable the busy man to go over the literature rapidly and pick out the documents he should read and perhaps study. Many excellent abstracting services now exist and I shall only name a few that are published in English: *Chemical Abstracts Service, Biological Abstracts, Applied Mechanics Reviews* and, in the field of metallurgy, the abstracts of the British Iron and Steel Institute, *Metallurgical Abstracts* of the British Institute of Metals, the *A.S.M. Review of Metal Literature.*

As a whole, abstracts are valuable timesavers, but they have many faults: There is too much duplication. There are too many omissions. There is too much of a time lag between the publication of the paper and the appearance of the abstract. There is confused and uncertain terminology. There is much bad indexing. The free world prepares in the average year about 300,000 abstracts and the Soviet Union prepares about 400,000, but duplication in these 700,000 is serious and only about one quarter of the available engineering and scientific literature is abstracted in any one year.

What I want to talk about especially is this periodical literature – the thousands of available papers that describe the results of research,

*Director, Engineering Foundation, New York. An address entitled "The Importance of Documentation" before the National Academy of Sciences, National Research Council, 1957 annual meeting.

applied science and industrial and technical developments, existing as reports in company or government files, or that are published in the *Transactions* or *Proceedings* of the professional societies and in technical journals. No library, so far as I know, has the available staff, either in numbers or in skills, to index and classify periodical literature so that it can be delivered to the specialized reader on demand, or even in a reasonable time. It is true that many libraries have all of the abstract journals, but these are for the most part inadequately indexed for use by the research worker; neither are they logically classified or coded. Hence the only way that an engineer or research worker can find out what is in the periodical literature is to dig it out for himself.

Twenty or 25 years ago this was not too great a chore. Suppose, for purposes of illustration, a director of research of a steel company in 1936 had an idea for a new stainless steel, and thought that its special corrosion resistance would depend on the composition, distribution, and behavior in heat treatment of the intermetallic compounds present. The first thing to do (and this is the first job that any research man would want to do) was to find out what was already known about these compounds.

The course of procedure was clear – it was used by all research workers at that time: The research director called in John Doe, a recent addition to the metallurgical staff at $200 a month, and gave him the problem. The first thing John Doe did was to read two articles in the 1936 "Metals Handbook" on the iron-chromium and the iron-chromium-nickel systems by two prominent authorities on these alloys, E. C. Bain and R. H. Aborn. These articles, like all well-prepared summaries, had bibliographies, and young Mr. Doe entered these references on cards. Next, he went over the abstract section of the *Journal* of the British Iron and Steel Institute for three or four recent years and thus accumulated 25 or 30 more references. He then read the articles containing data on iron-chromium compounds, either in his company library or at the Carnegie Library in Pittsburgh, or, if necessary traveled to the Engineering Societies' Library in New York. As he read these papers he recorded the bibliographic references attached to them which seemed pertinent to iron-chromium compounds. These documents were then scanned and the relevant data recorded.

At the end of ten days or two weeks, or a month at the most, he was able to present his director with a concise, complete summary of all that was known about the compounds in the iron-chromium-carbon and other iron-chromium systems back to the time the compounds were first isolated and studied, at a cost not exceeding $200 or at the most $300. In addition, Mr. Doe from his reading was already something of an expert on these alloys and their intermetallic compounds, and he was able to help the director outline the program of research and to carry it on successfully and economically.

Experimental Literature Searching Machine Developed at Western Reserve University

Now let us see what would be involved today in finding out what has been done on a specific problem. The method just described is still used, but the difficulties are great and they are becoming greater year by year. It is still used because there is no better method available. Yet there are three major difficulties to surmount.

In the first place, the output of technical literature has increased at a startling rate. The major American engineering societies publish in an average year about five times the number of technical papers published 20 years ago. In 1956, *Engineering Index* prepared 27,000 abstracts in all fields of engineering. In metallurgy alone, *Chemical Abstracts* printed 3735 abstracts, the Iron and Steel Institute of Great Britain printed 5100, the British Institute of Metals issued 7600 and the Review of Metal Literature listed 8450 items in its field. Even allowing

for the inevitable duplication, reviewing the literature in any branch of metallurgy is a labor worthy of Hercules; and there is no certainty that important papers have not been missed.

The second difficulty is that few companies have the technical manpower available to make a review of the extensive literature before beginning a research job. Furthermore, few young scientists and engineers are interested in doing what they term "a library grind."

Lastly economics and manpower enter in. Recent graduates in metallurgy are no longer available for $200 a month. When one considers the high cost of manpower, the long time needed to make a thorough search of the literature even in a restricted engineering field, and the much greater expense of sending a metallurgist to a city where a fine periodical collection is available, the cost of searching the literature has increased manyfold beyond what it was 20 years ago. In fact, the difficulty and cost have pyramided to the point that some months ago the vice-president for research of one of this country's large corporations made the following astounding statement: "If a research job costs less than $100,000 it is cheaper for us to do it than to find out if it has been done before and is reported in the literature."

This statement points up a situation that is rapidly becoming intolerable.

What is the answer? I think it requires a three-pronged attack: First is the development of a logical and uniform system of indexing based on semantic principles. Second is a logical system of classifying technical papers or abstracts to technical papers which will permit them to be coded effectively and rapidly. Last is the development of some system, preferably by the use of machines, which will rapidly locate and retrieve the coded literature.

What is being done on this threefold attack on the problem? Very little in the whole field of engineering. During the last ten years the problem has been extensively discussed, but only a little of the talk has resulted in action—except in the field of metallurgy. This has been due to the foresightedness shown by the American Society for Metals in sponsoring three activities.

1. In 1944, A.S.M. established a monthly abstracting service, the ⊕ *Review of Current Metal Literature*, which covers the field of metallurgy with considerable thoroughness and unusual promptitude.

2. In 1948, the A.S.M. foresaw the need for a system of classification of terminology of metallurgical papers and abstracts which would permit coding by logical classes. The first classification was published in 1950 and was designed for the benefit of the many research metallurgists who maintained a private file of pertinent literature, or for the metal company librarian. It is known as the ASM-SLA Metallurgical Literature Classification. It was designed to be used either as a classified subject index (file folders or ordinary 3×5 cards) or in conjunction with hand-sorted punch cards (a simple "machine"). It is in use in several hundred company and private collections both here and abroad. In 1954 A.S.M. decided that the classification needed revision, and the Board of Trustees appointed a new committee to do the job. The job is done and the new and greatly improved classification will be published in a few months.

3. In 1955, A.S.M. appropriated a considerable sum of money to establish a pilot-plant project at the School of Library Science at Western Reserve University to determine if machine methods of searching and finding coded metallurgical literature are practical. This study will last five years. Progress to date seems to indicate that a coding system adaptable to machine feed is being successfully formulated. Six thousand metallurgical abstracts have already been encoded and trial runs made on a simple machine constructed by the University to determine the degree to which electrical devices can correlate various metallurgical concepts.

The American Society for Metals hopes that its threefold attack on the problem will at least spur other organizations in the engineering field to action, eventually to finding an answer to what is now one of the most pressing problems in the whole field of engineering – making the literature readily available.

If an answer is found – and I believe it will be found – we will solve once and for all time the unpleasant and undesirable problems that exist today, namely the economic problem (which is the high cost and waste of manpower in repeating work which has already been done but which cannot be found) and the ethical problem of reporting as new and original, data which should be credited to some previous investigator. ⊕

EDITOR'S ADDENDUM – Readers who are interested in more information on the ⊕ projects can refer to the articles "Machine Searching of Metallurgical Literature" in *Metal Progress* for February 1957, and "Classification of Metallurgical Literature" in the June issue. A 15-min. sound-color film "The Metals Information Center of Tomorrow" will be shown at the forthcoming National Metal Exposition in Chicago, Nov. 4 to 8, by the Center for Documentation and Communication Research of Western Reserve University.

Testing of Welded Aluminum Hopper Cars

*By J. F. WHITING**

About 150 aluminum freight cars of three designs have been made by Canadian car builders. To devise improvements strain gages were placed at strategic positions on full-sized hopper cars. These are of welded construction using strong aluminum alloys, sheet and extrusions, even to the center sill. Stresses were measured during static, shake-out and impact tests simulating actual service conditions. (T23p, 17-7, S21; A1, 17-1)

WHILE ALUMINUM sheathing is commonly used on new passenger-car equipment, and some aluminum tanks and hoppers on freight cars, we believe that Canada leads in the manufacture and use of aluminum hopper-bottomed cars. This extension of the strength-weight idea from aircraft to railroad equipment goes as far as welding the entire structure down to and including aluminum center sills.

History

Ninety 70-ton Canadian-made aluminum hopper cars were placed in service hauling bauxite, sulphur and coal by the Roberval and Saguenay Railway (R. & S.) between 1948 and 1951, and in 1951 the Canadian National Railways (C.N.R.) ordered five cars of this type. The riveted bodies were made of Alcan 65 S-T 6 (U. S. 6061-T 6) plate and extrusions and Alcan 55 S-T 6 A (U. S. 6053-T 61) rivets. Although a standard steel underframe was used, the weight saved was 12,000 lb. per car. Little maintenance has been necessary on these cars because aluminum is very resistant to erosion and corrosion by the commodities they haul.

In 1955, 28 open hopper cars with aluminum body were built for the R. & S. by Canada Car & Foundry Co. Although they have a rated capacity of 70 tons they regularly carry 87 tons. The bodies were fabricated by welding but the experience gained in operating the earlier riveted cars was used in their design.

In 1953, 13 covered aluminum hopper cars were built by the Gregg Co., Ltd., for Alumina Jamaica, Ltd. (Aljam) to a steel design modified but slightly to suit aluminum. The center sill was built up from aluminum extrusions by welding and riveting. Early in 1956, 16 similar cars were built for Aljam by Marine Industries, Ltd. These were the first to have an all-welded aluminum center sill of the American Association of Railroads (A.A.R.) type.

At first, aluminum was merely substituted for steel; but, in the last group of 16 cars the design was changed to suit the properties of aluminum. To prove the soundness of this design it was necessary to conduct static, shake-out fatigue, and impact tests on a completed car which would simulate service conditions. These tests, the first of their kind to be carried out in Canada, were conducted by Aluminium Laboratories, Ltd, of Kingston, Ont., and were sponsored by the Aluminum Co. of Canada, Ltd. Parallel tests were made on one of the R. & S. open hopper cars built in 1955. Canada's two major railways rendered valuable assistance.

Static Tests

The all-welded, covered aluminum hopper car under test is shown in Fig. 1. It has a rated capacity of 50 tons and was fabricated from Alcan 65 S-T 6 (U. S. 6061-T 6) extrusions and

*Aluminium Laboratories, Limited (A Member of the Aluminium Limited Group), Kingston, Ont.

Fig. 1—All-Welded 50-Ton Hopper Car With Aluminum Center Sill. This car is roofed with ⅜-in. aluminum sheets. It is all aluminum alloy except for trucks and draft gear

Alcan B 54 S-F (U. S. 5054) plate. Side sheets were ¼ in. thick, the side posts were formed from plate 5/16 in. thick and roof sheets were ⅛ in.

SR-4 electrical resistance strain gages were located where the major stresses were anticipated. Switching and balancing units connected them to a strain indicator and recorder.

The car was loaded with water and strains were recorded at several load increments up to the rated capacity of 100,000 lb. Deflection of the center sill was measured against a stretched piano wire and by a surveyor's level directed at targets fastened to the sill under the bolsters, and at its center. Vertical deflection of the sidewalls of the car, acting as a plate girder, was also measured by a surveyor's level.

The results of the static loading may be summarized as follows:

1. Loading to capacity produced a maximum stress of 6350 psi. in the vertical post and 6000 psi. in the adjacent panel. These stresses should not be critical since they occur on the face of the post and at the center of the panel. The maximum stress observed in vertical welds was only 3150 psi.; since it was a compressive stress it should not be critical, even in fatigue.

2. Stresses in the top and bottom chords of the sides, in the bolsters and in the center sill, were below 1500 psi. Hence for this condition of loading they were relatively unimportant.

3. Vertical deflection at the midpoint of the center sill was 0.10 in. and of the sidewalls was 0.04 in. Thus, the sidewalls were sufficiently stiff to carry all the load out to the ends of the car, rather than to transfer it to the center sill in bending. The measurements indicated, however, that it would be desirable to stiffen the center sill.

It was concluded that the static loads were not excessive for the aluminum alloys used in the car. Although it was loaded with water it can be expected that similar stresses will be encountered in hauling alumina, since it has a very low angle of repose and would produce a similar side thrust.

Shake-Out Fatigue Tests

The open hopper car from the R. & S. Ry. for shake-out fatigue tests at Arvida, shown in Fig. 2, was built in July 1955 and has a rated capacity of 70 tons. The Hewitt-Robins shake-out shown applied an oscillating force of 36,000 lb., at 24 cycles per sec. to a mass of 10,820 lb., sitting on top of the sidewalls. Thirty-six SR-4 strain gages were fixed at strategic locations and recorded by a Brush oscillograph.

The shake-out operated on the empty car for 20-sec. periods for the first 8 min., then at periods varying from 10 sec. to 10 min. for the remainder of the test. After each period the car was inspected for damage. The short shaking periods at the beginning of the test permitted readings to be taken from all strain gages before damage occurred.

The maximum alternating stress measured was about 8000 psi., and occurred both at the center of the panel immediately under the car shake-out, and at the joint between top member and car side, also immediately under the shake-

Fig. 2 – Welded Aluminum Hopper Car, 70 Tons Capacity, Ready for Shake-Out Fatigue Test. This car has standard steel center sill riveted to the aluminum body

out. The large number of strain gages gave a clear picture of the distribution of stress throughout the car sides, information which will be most useful in future designs.

Relatively small changes in joint design and in the size of fillet welds would give the critical parts of this car a considerably longer fatigue life. A comparison of the performance of this aluminum car with that of welded steel hopper cars, tested under similar conditions, showed that the aluminum car performed as well or better than the steel ones. With the suggested modifications in design the performance of this car would be outstanding.

While the Aljam covered aluminum hopper car was not designed originally for shake-out, it was adapted to receive the equipment by welding appropriate pieces of aluminum plate along the top of the side panels. Strain gages were attached and tests performed similar to those just described.

From a comparison of the performance of the two cars, it would appear that fewer and lighter side posts, with larger and less rigid panels, would produce a car having excellent fatigue life against shake-out stresses.

Impact Tests

The final tests in this program were designed to determine the effect of impact loads up to 1,000,000 lb. on the center sill and car body. The distribution of the stresses throughout the sill and body was also studied.

The covered hopper car shown in Fig. 1, already subjected to the previous tests, was used after the defects caused by fatigue during shake-out were repaired by welding. It was already known that the connections between the car body and sill were inadequate. Therefore, the connections were reinforced by diaphragms under the hopper peaks and at each end of the car and additional end-sill braces were added. The car was then filled with crushed rock to give an "on-the-rail" weight of 168,000 lb.

The standard Type-E couplers were removed from the striking ends of the two cars involved in the test. The coupler on the moving or strike car was replaced by a solid steel block machined to fit into the coupler socket, while the coupler on the standing test car was replaced by a dy-

namometer. Impact between the two occurred on a 3.8% grade at velocities from 2 to about 15 mi. per hr.

SR-4 strain gages were placed on the dynamometer block and at 21 different locations on the test car, including the center sill and end braces, the bolster truss, a side post, diaphragms and hopper ends. Strains were recorded on two oscillographs having a total of 20 channels.

The general procedure was to spot the strike car at a predetermined distance up the grade. After the oscillographs were balanced and calibrated, the brakes on the strike car were released. The limit switches of the braking systems were located so that the brakes on the strike car were automatically applied at the moment of impact while those on the test car were actuated about 2 ft. down the grade from the point of impact. After each run the test car was inspected for damage.

Two series of tests were conducted with maximum impact of approximately 900,000 lb. In the first series the test car was free to move. In the second series the test car was backed-up by four fully loaded box cars. In a third series of tests rubber draft gear replaced the friction draft gear in the strike ends of both cars.

The results of 75 impact tests show that the aluminum center sill successfully withstood impact loads up to 947,000 lb. It is confidently expected that it would carry considerably higher loads, since the present tests were limited by the failure of the draft gear lugs and not the center sill itself. Fig. 3 shows the stresses in the center sill in the three test series. Similarly, no appreciable differences in stresses were found in the car body when it was backed up by the fully loaded boxcars.

The impact tests revealed that, for this design of covered hopper car, the connections between the car body and the center sill were the weakest points. The modifications made to these connections prior to the impact tests, as noted above, were a definite improvement over the original design, but can be improved still further. As a result of the tests new designs have been prepared which will produce a stronger car without additional material. Such cars are now on order.

The most damage in these impact tests was suffered by the friction draft gear. In the final test the steel draft lugs failed completely, driving the rubber draft gear back into the center sill. There was no appreciable bulging of the end or side sheets, which indicates that the body design was adequate for the impact loads involved.

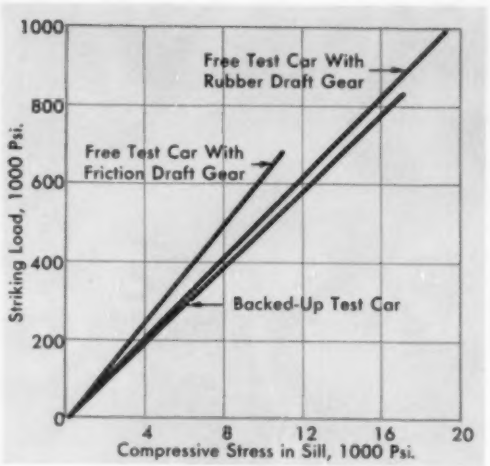


Fig. 3 — Average Compressive Stresses in Aluminum Center Sill of Test Car Induced by Impact With a Moving Car Through the Draft Gear. In the free tests the car was free to move along the track after impact; in the third test series the car was backed up by four loaded freight cars

Conclusions — Static shake-out fatigue and impact tests have shown that welded aluminum hopper cars will withstand conditions more severe than those normally encountered. The tests also indicated the desirability of relatively minor changes in design which will improve still further their outstanding performance. The principal changes are in the connections between the car body and the center sill, the number and location of side posts, and the number and size of end sill braces.

In fine, this testing program has proved that aluminum is an excellent material for welded railway hopper cars and has provided information by means of which future cars can be made even better. These new aluminum cars can be expected to withstand even better the severe treatment normally given this type of equipment. In addition, the light weight of aluminum means that dead weight is reduced and payload is increased. Fewer of the lightweight cars are required to carry a given quantity of freight, thus reducing switching and line hauling time. Less maintenance is necessary because of the excellent resistance of aluminum to the weather and to most of the corrosive materials being hauled.

The economies realized through the use of aluminum are indeed real, since once an aluminum car is placed in service it normally requires no further attention to maintain its appearance and serviceability.

Induction Heating for Merchant Mill

By R. S. SEGSWORTH*

Billet-sized ingots are pushed end to end through a long induction coil, the first half of which receives 60-cycle current and the second half 540-cycle current. A 6½-in. square reaches rolling temperature in 8.4 min. Indicated scale loss of 3% in oil-fired heaters has been reduced to less than 1%. (W20h; 1-19; CN)

WIDESPREAD APPLICATIONS of induction heating have been based on the use of comparatively high frequencies. By "high" frequencies is meant a few thousand cycles per second – high in comparison with the 60-cycle current which is almost the universal standard for power distribution systems. In fact, within the last decade or so it has been found that *very* high frequencies (approaching radio) are very good for special jobs, usually where a very thin layer on the surface is to be heated.

It might therefore be supposed that the other end of the spectrum – line frequencies and frequencies of a few hundred cycles per second – might be equally good for thorough heating of heavy pieces, like steel billets for rolling or forging. This is indeed true, as the following article will demonstrate. But before we start it might be remarked that induction heating with 60-cycle current is not new. It was used in the 1930's in the United States for surface heating of steel automotive parts. Today, most aluminum extrusion billets are heated with 60-cycle current, and a considerable portion of the other nonferrous extrusion billets.

The method has had an outstanding success in numberless special applications. Users generally have been impressed with the ease of control, the rapid heating, the excellent surroundings for workmen's comfort, and the adaptability of the process to automation.

With a little imagination and some careful engineering it has now been shown that in the relatively straightforward heating of heavy sections, such as steel billets, the induction method may be applied economically and with the acknowledged advantages already proven in the special fields.

For best efficiency and lowest capital cost, the frequency chosen must be well suited to the work in hand. For many of the heavier jobs it has been found that all or at least part of the power may be applied at 60 cycles, thus eliminating or reducing the amount of frequency-converting equipment. This is well illustrated in a unit installed some three years ago at Vancouver Rolling Mills in British Columbia. This furnace is heating mild steel ingots for a 16-in. merchant rolling mill producing reinforcing steel, merchant bars, light angles and channels. All the production passes through this furnace. The general arrangement is shown schematically in Fig. 1.

Since an electric furnace is used to make the steel which is cast into the small ingots, this steel plant is unique in that (starting with scrap) the plant carries the operation through to the finished product without using a single ounce of solid or liquid fuel. The entire operation consumes as much electricity as the adjoining city of New Westminster, approximately 4,000,000

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kw-hr. per month, in making some 5000 tons of marketable product.

The heating furnace was required to handle a range of tapered cast ingots from 3 to 6½ in. square, weighing from 96 to about 465 lb. These of course are not "large" ingots to a plant operating bessemer converters or openhearth furnaces. However, in British Columbia, as in several locations in the States, a very profitable operation has been based on electric furnace melting of an all-scrap charge, furnaces which in turn cast a moderate sized ingot (no larger than billet sizes in many mills) not needing a heavy and very expensive blooming mill for breakdown.

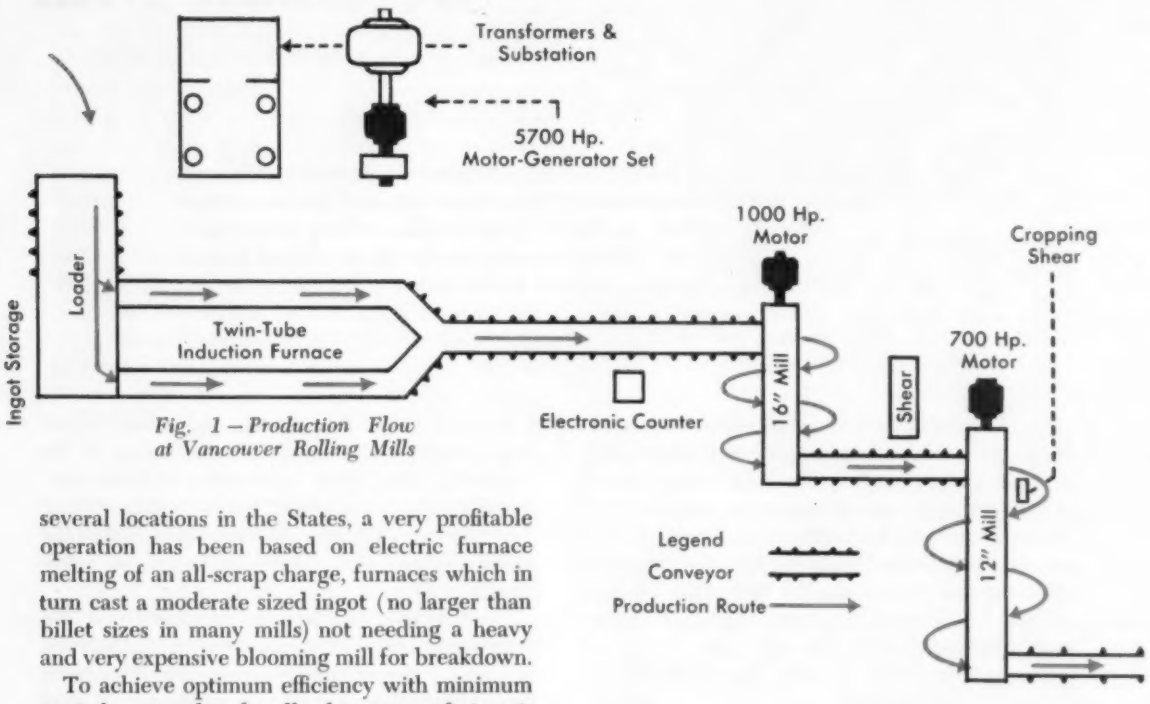


Fig. 1 — Production Flow at Vancouver Rolling Mills

To achieve optimum efficiency with minimum capital cost and to handle this range of sizes it was possible to put in half of the power at 60 cycles in the first third of the furnace and the balance at a higher frequency (540 cycles). A slightly different apportionment of power input would give better efficiency for the largest cross sections, but the system chosen was an average. The electrical and mechanical complications of an adjustable system were judged to be impractical. Again, to keep the over-all length of the furnace within reasonable limits the unit was designed with two identical parallel tunnels, each with a continuous line of ingots, pushed end to end. This arrangement also provides some additional adaptability since either side may be operated independently.

The ingots are heated as they travel through helical coils carrying the current. These coils are made of insulated copper tubing through which cooling water is passed. The coils are lined with and encased in refractory, which provides mechanical protection from the hot steel inside and casual abuse from the outside.

Cold ingots are brought as required from the storage yards by fork-lift trucks and placed on a table fitted with walking beams. These spread out the bundles of ingots and pass them to another roller table which carries them forward to the hydraulically operated feeder shown in Fig. 2. The feeder pushes the ingots one at a time as required to one side or the other, where hydraulic rams push them end-on into the heating tunnel. Interlocks keep the two lines in step so that ingots are fed to the rolling mill at regular intervals. The discharge end of the dual furnace is shown in Fig. 3.

All operations are controlled from a pulpit set between the two lines above the furnace with appropriate mirrors so the operator has a good view of both ends of the furnace, and also down the length of the rolling mill. From this point the operator can adjust the rate of feed and the power input. He also has control of the roller conveyer which carries hot ingots to the mill. (A gate is provided in this table, so ingots may be sent into the mill or set aside.) Appropriate meters indicate the current, voltage and power in the various circuits. Radiation pyrometers wired to indicators in the control pulpit sense the

temperature at the end of the 60-cycle zone and at the middle and the end of the high-frequency zone. The pulpit operator can vary either the rate at which the billet-line is pushed through the tunnel, or the power input at 60 or 540 cycles to adjust the output of properly heated metal up to the capacity of the rolling mill or of the heating tunnels.

Power supply is brought into the plant at 60,000 volts and stepped down in three 3000-kva. transformers to 4000 volts. Power for the 60-cycle end of the furnace is stepped down again from 4000 volts to 500 volts in a 4000-kva. three-phase transformer, with off-load tap-changing equipment. The high-frequency power (540 cycles) is obtained from a 3500-kw. alternator, driven by a 5000-kva. synchronous motor operated at 4000 volts.

Conventional air-cooled capacitors correct the power factor on the 60-cycle end, and the power factor is corrected to approximately unity under most conditions. The capacitors used for the high-frequency coils are water cooled and the power factor is held at unity or slightly leading.

Temperature is controlled by changing the voltage on the 540-cycle circuits, done very easily by adjusting the generator field current. Watt-hour meters measure the power from the 4000-v. bus, and it has been established that the power consumption on the largest ingots is approximately 300 kw-hr. per ton of metal heated for rolling. The largest ingots are heated at the rate of 20 to 25 tons per hour. With the smaller ingots, the average power consumption is somewhat higher and the rate of production somewhat less.

One of the most striking features of the new operation is its speed. The total heating time ranges from 3.6 min. for the smallest ingots to 8.4 min. for the largest. Something less than a total of 10 min. elapses from the time a large ingot enters the furnace until it is a finished bar on the cooling bed. Thus there is a relatively small tonnage of material in process at any time, and the furnace may be started or stopped practically at the touch of a button.

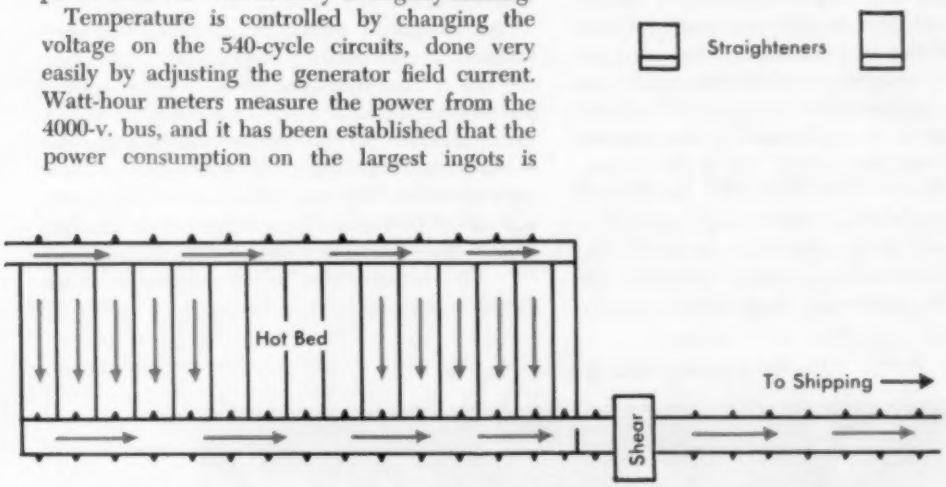
For cooling the induction coils and other devices the water is recirculated to two open cooling towers. This provides the necessary water for cooling the 60 and 540-cycle coils, the 540-cycle capacitors, the 3000-kva. transformers, and the 540-cycle alternator. The maximum flow of cooling water is over 500 gal. per min.

Operations

The furnace operates with a total of four men per shift. Working conditions have improved immeasurably as compared with what existed when ingots were passed through fuel-fired furnaces. The men are at no time subjected to heat, and can work in perfect safety and comfort throughout the entire operation.

The problems encountered in putting this unit into operation were not out of proportion to its size and unique nature. Testing prior to completion was necessarily limited. Heating tests were limited to a single ingot and it was quite impossible to duplicate operating conditions, even approximately. Despite the size and unique requirements of the job, it was designed, built and installed in record time. The order was placed in November 1953 and the furnace went "on the line" by the end of the following July. It has been in continuous operation ever since.

Naturally certain operating problems arose, since this was a pioneer application and there was no bank of previous experience in actual production. However, production was maintained on the new unit from the very start. Once



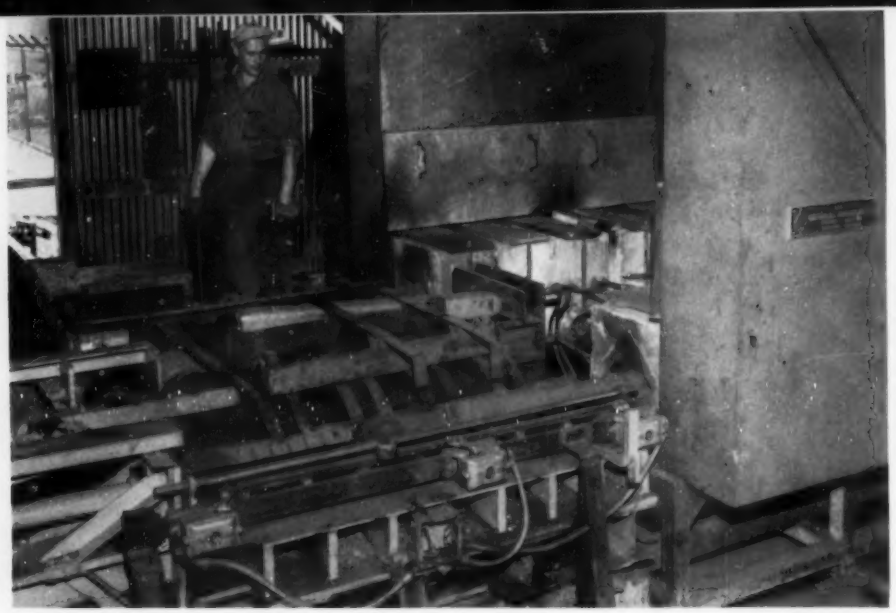


Fig. 2 – Feed End of Induction Furnaces for Heating Small Ingots. One Ingot has been delivered by roller table from the right against a slot. Here it is ready to be pushed sideways (toward the operator). In foreground is an ingot partially pushed into the near heating tunnel

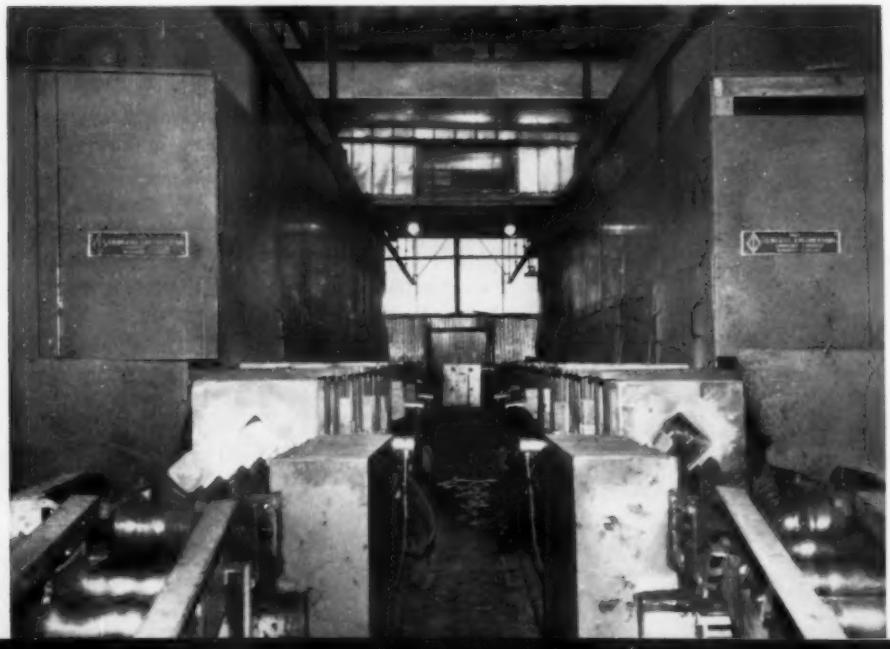
the operating and maintenance crews had gained some experience, interruptions due to furnace trouble became very rare.

The installation is simple and compact. Since the heating coils remain cold, practically no heat radiates into the surroundings. One can approach, with complete comfort and safety, to within a few inches of hot steel within the tunnels. Heating is so rapid that there is a minimum opportunity for scaling. Control is simple, quick and effective. In short, this installation has made available – economically and in a large unit – all those advantages normally associated with induction heating technique on small parts like automotive crankshafts.

The results achieved may be judged by the following extract from a report by M. C. D. Hobbs, general superintendent of the Vancouver Rolling Mills:

"As compared with the previous fuel-fired furnaces the installation requires approximately 160 fewer man-hours per shift; in addition, the production of finished steel has been increased by approximately 30% as compared with the previous operation. The electrical energy costs approximately $1.00 per ton less than the previous cost of fuel oil. The indicated scale loss has been reduced from an estimated 3% to less than 1%. This has also resulted in a better finish on the final products."

Fig. 3 – Discharge End of Dual Furnace



Vacuum Induction Melting–Process Considerations

*By W. E. JONES**

Successful vacuum melting requires very high vacuums, leak-tight equipment, pure melting stock and crucible materials. Reactive metals added at the end of the heat then alloy with the melt rather than form undesirable inclusions. Notable improvements result in high-temperature properties of heat resistant alloys. (C5, 1-23; SGA-h, Ni, Co, Fe, 5-9)

THE ART of vacuum melting goes back to the turn of the century. In the German work during the 1920's the major interest was in degassing. The philosophy of melting was somewhat different then from what it is now.

The vacuums used were low in comparison with what we use today — for one reason because proper pumps were not available. Nevertheless considerable amounts of special steels (particularly bearing steels and toolsteels) were made and advantages obtained. Much magnetic alloy was also made in vacuum furnaces.

Further progress awaited the large oil diffusion vacuum pump in the late 1930's, which had large capacity in the micron range of pressures. The electromagnetic process for separation of the isotopes of uranium, as perfected at Oak Ridge, was responsible for a large amount of vacuum technology during World War II, and was immediately applicable to metallurgy.

The jet engine, with its requirements for materials to operate at very high temperatures, was the impetus which started the true vacuum melting industry in the United States. Consider the operating temperatures of "superalloys" in production over the past 15 years. A representative temperature for turbo superchargers operating in 1940 was about 1275° F.; this jumped to about 1475° F. in the next five years but then increased hardly at all until 1952. Vacuum melting then made a significant contribution, temperatures now being in the region of 1650° F., with all evidence pointing to the continuation of this trend.

*Metallurgical Products Dept., General Electric Co., Detroit. This paper will be presented at the meeting of the Industrial Heating Equipment Assoc. at the ⊕ Annual Meeting in Chicago on Tuesday, Nov. 5, 1957, and is based on a lecture given before the Seminar on Vacuum Metallurgy at New York University in June 1957.

Purposes of Vacuum Melting

While this paper will deal primarily with how to melt, rather than what vacuum melting does, it is desirable to recognize that there are some inherent advantages to be gained. These can be summarized in the statement that alloys can be produced which are much cleaner and stronger than those melted in air.

This improved cleanliness of bearing steels, for example, results in large increases in performance which is so necessary in critical applications. A.S.T.M. inclusion rating for vacuum induction melted 52100 steel is 1 to 1½ thin inclusions, whereas air melted (basic electric furnace, alloy practice) is 2½ thin and 2 heavy inclusions. This difference is also seen in the fracture test (Fig. 1). Finally, fatigue tests on the steel and on assembled bearings made at room temperature show considerably higher endurance limits than for the air melted product.

This control of cleanliness applies to other vacuum melted materials, properly produced. But there are alloy compositions in which it becomes exceedingly difficult, if not impossible, to achieve this high degree of cleanliness; for

instance, high manganese and silicon contents in low-alloy steels contribute to greater quantities of inclusions.

A second part of the story is the simultaneous improvement in mechanical properties of the alloys when tested at high temperatures. The rupture and creep strength can be significantly increased as full advantage is taken of the strengthening effects of aluminum, titanium and zirconium additions when they are not tied up as oxides or nitrides. The magnitude of these differences for General Electric's alloy M-252* is as follows:

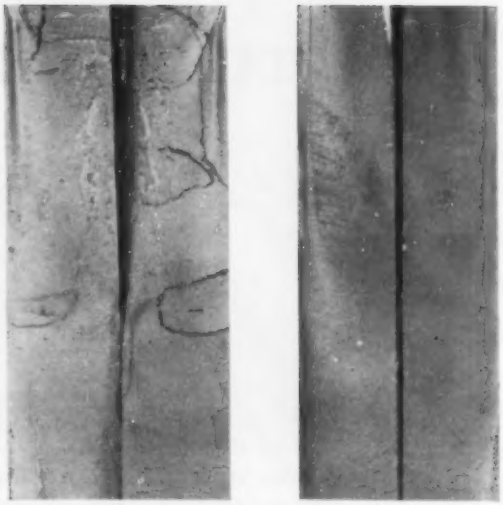
Property	Air Melted	Vacuum Melted
Stress to rupture in 1000 hr. at 1500° F.	15,000 psi.	20,000 psi.
Fatigue stress, 10^8 cycles at 1500° F.	42,000 psi.	50,000 psi.
Elongation in short-time tensile test at 1350° F.	7%	16%
Yield, ingots to bars	44%	66%

Beyond this, new alloys can be developed which are stronger than those we have had in the past, as is indicated in Mr. Jahnke's article on p. 113 of this issue. There are already several such alloys on the market. These iron, nickel or cobalt-base alloys utilize larger quantities of reactive elements and cannot normally be produced in a furnace melting in air atmosphere. Such materials as Udimet 500† and G.E. Alloy J-1570‡ are considered in this category and their properties are reflected in the increase in working temperatures of jet engines since 1952.

A final advantage of vacuum melting is the high degree of uniformity in properties of the final product, ingot to ingot and heat to heat. Some of this may be due to the high quality of raw materials and the extreme care used in production, but most of it is due to the utilization of vacuum technology and the elimination of many variables associated with air melting.

Equipment for Vacuum Melting

A vacuum melting unit, in its simplest form, consists of an induction furnace inside a vacuum tank, with suitable pumps, power and auxiliaries. Many designs and modifications are now actually producing good metal in the United States, ranging in capacity up to those capable of producing heats of 3000 lb. on a regular basis.



Air *Vacuum*

Fig. 1 – Improved Cleanliness of Vacuum Induction Melted Bearing Steel (A.I.S.I. 52100) Is Apparent When Fracture Disks Are Compared With the Same Steel Made in Basic Electric Arc Furnaces

There are many different ideas about the desirability and the manner in which furnaces can be loaded and unloaded. A schematic drawing of the unit operated at the metallurgical products department of General Electric Co. in Detroit (Fig. 2) will show how one can operate almost on a continuous basis.

This is a 1000-lb. furnace with a 7-ft. diameter melting tank and separate, valved-off tanks, one for additions and one for ingots. An oil diffusion pump of 18,000-liter per sec. capacity at 4 microns and two mechanical roughing pumps make up the vacuum system. The tank can be evacuated to 0.5 micron and it can be held at 1 micron or less with 1400 lb. of molten metal in the furnace. The power supply is 350-kva., 440-v., 960-cycle current, introduced through a co-axial port so that power can be on for any furnace position.

If there is one feature to be singled out to explain the successful performance of this unit, it is the ability to make numerous consecutive heats without breaking the vacuum on the melting tank. It has been operated for as much as a week at a time without opening the melting chamber to the atmosphere. Such performance contributes markedly to the efficiency of operation and the quality of the products.

Frequently the use of extremely low pressures is questioned. This is a consideration that has

*Nominal composition of M-252 is 53 Ni, 19 Cr, 10 Co, 10 Mo, 2.5 Ti, 2.5 Fe, 1.0 Al, and 0.16 C.

†Nominal composition of Udimet 500 is 50 Ni, 18.5 Cr, 18.5 Co, 4.0 Fe, 4.0 Mo, 3.0 Al, 3.0 Ti, 0.08 C.

‡Nominal composition of G. E. Alloy J-1570 is 39 Co, 30 Ni, 20 Cr, 6.5 W, 4.1 Ti and 0.2 C.

an important bearing on economics. Such low pressures – on the order of a few microns – are quite expensive, both in the cost of vacuum pumps and in the time required to complete the melting cycle.

From the theoretical point of view, the lower pressures are generally desired to further the reactions that take place – and certainly the history of the industry shows an improvement in the ultimate vacuum obtained. But factual data comparing an improvement in a property as the degree of vacuum increases are very limited. We have some data on rupture life and elongation at fracture of two alloys which help establish orders of magnitude.

G.E. Alloy J-1570 at 1500° F.

Vacuum	Rupture Life at 30,000 Psi.	Elongation
400 to 800μ	125 hr.	10%
20 to 70μ	245	17

Udimet-500 at 1600° F.

Vacuum	Rupture Life at 25,000 Psi.	Elongation
1000μ	80 hr.	6%
10μ	200	14

Two heats of the cobalt-base G. E. Alloy J-1570 were made in the pressure range of 400 to 800 microns, and they could be directly compared with metal melted as in production, in the range of 20 to 70 microns. The heats made at the higher pressure had lower rupture strength and lower ductility in the rupture test. Experimental heats of Udimet-500 made at 1000 microns (using the roughing pump only) and at 10 microns (using the diffusion pump) show a similar trend.

On the other hand, there are times during a melting cycle when it is desirable to use pressures of a few millimeters. Sometimes the evolved gases are allowed to accumulate; at other times an inert gas such as argon is introduced into the tank. Generally it can be said that such pressures in the range of 10 to 70 mm. are successfully used, first to control splashing and a tendency to form a ring at the top of the crucible during melt-down; second, to control carbon boil, and third, to reduce cavities in alloy steel ingots where the gas solubility is so high it is difficult to obtain sound ingots.

Pressure built up by the evolved gases appears more effective than an inert gas in slowing down the carbon reduction reactions in liquid steel. It certainly makes it more difficult to start up again, and there is evidence that the degree of deoxidation was impaired. This has been determined by measuring the time required from melt-down to attaining a given "leak-up rate" prior to the time that additions are made.

Leak-Up Rates

The vacuum measured in the furnace system in only part of the story. Of equal and possibly greater importance is the leak-up rate, or the manner in which the pressure in the melting tank behaves when the valves to the pumps are closed and the total pressure rise in a given period of time is recorded.

This increase in pressure may be due to air leaking into the tank, to adsorbed gases from the tank walls or the furnace parts, to water leaks, or to gases coming out of the liquid metal. Since one of the prime purposes of vacuum melting is to hold the oxygen and nitrogen to extremely low levels to prevent reactions with hot metals, it is probable that the leak-up rate is a more truly indicative measure of the quantities of gases actually present and in contact with the molten metal's surface than the actual pressure reading in the tank.

The pumping system can be of sufficient size that it can maintain low pressures even though large quantities of gases may be passing over the liquid metals. For instance, a pressure of 1 micron can be measured in the tank, yet (on blanking off the pumps) the leak-up rate will be 100μ per min. Experience has shown that this is an excellent indicator of the conditions present and it is given due consideration during a melting cycle.

Before a heat is produced in our Detroit facilities, the total leak-up rate in the cold tank must not exceed 5μ per min. If it is larger it is an indication of leaks or large quantities of adsorbed gases in the system, and these may cause undesirable reactions during melt-down. The leak rates due to adsorbed gases should diminish as consecutive heats are melted without opening the tank to atmosphere, and this has been observed to be the situation. Leak-up rates in a cold furnace under these conditions are from 1 to 2μ per min.

This same type of measurement is used in production melting to determine when the final additions of reactive elements will be made to the melt. In this instance, one is interested in knowing the progress of the gaseous reactions, so additions are not made too soon (while oxygen and nitrogen are still present). Predetermined values of leak rates have been set up as control measures to assure uniformity of

product, even though the exact required values are not known.

Again, it is difficult to substantiate with actual test data what common sense tells us we must control to fairly close limits. We do know that leak-up rates and pressures decrease with consecutive heats. At the same time, oxide-type inclusions in bearing steels are reduced. A relationship is suspected.

Some information on the effect on high-temperature properties is available from a series of tests conducted on heats of the nickel-base, age hardenable alloy Udimet-500 in which the leak rate to air was varied only from 10 to 300μ per min. (In all tests the pouring pressure varied only from 10 to 17μ.) Results are summarized in Fig. 3. With the leak rate varying over this range the rupture life (25,000 psi. at 1600° F.) is reduced from an average of 170 hr. to 75 hr. There is also a decrease in ductility in both the short-time tensile test at 1200° F. and in the rupture test at 1600° F.

In analyzing the data available, the correlation shown in Fig. 4 has been found between the oxygen content of the metal and the rupture life in hours. A similar correlation exists between oxygen content and the ductility values. Oxygen contents as high as 260 ppm. were found

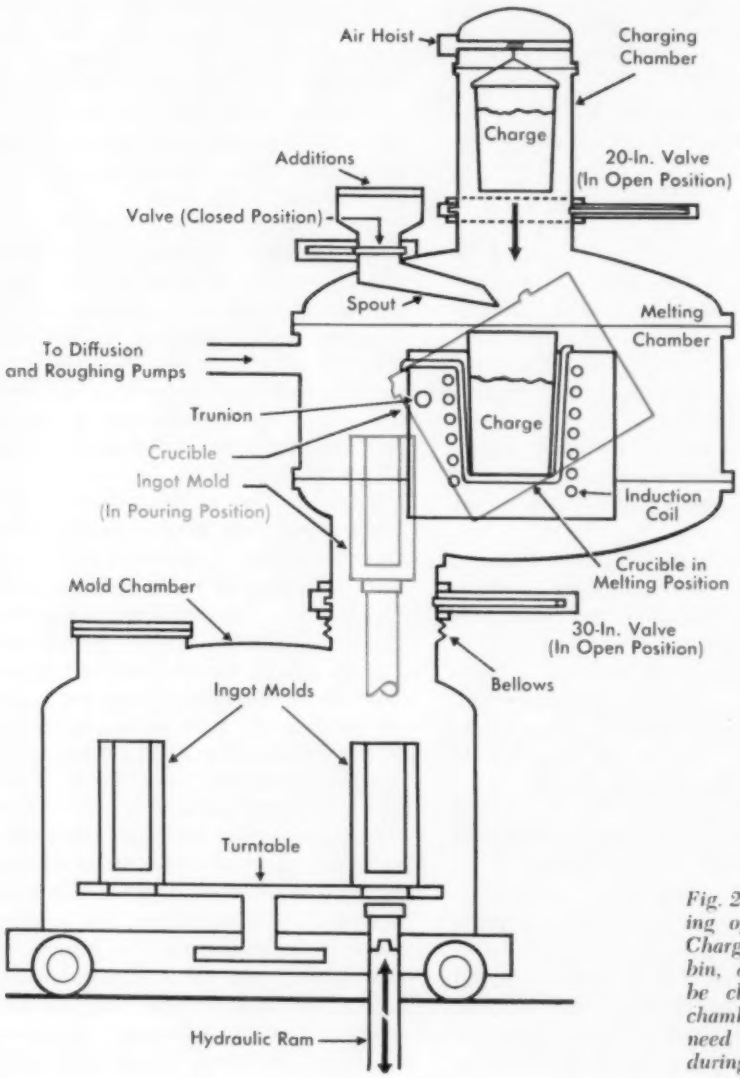


Fig. 2 – Cross-Sectional Drawing of Complete Equipment. Charging chamber, additions bin, and mold chamber can be closed off from melting chamber so vacuum in latter need not be broken even during a lengthy series of melts

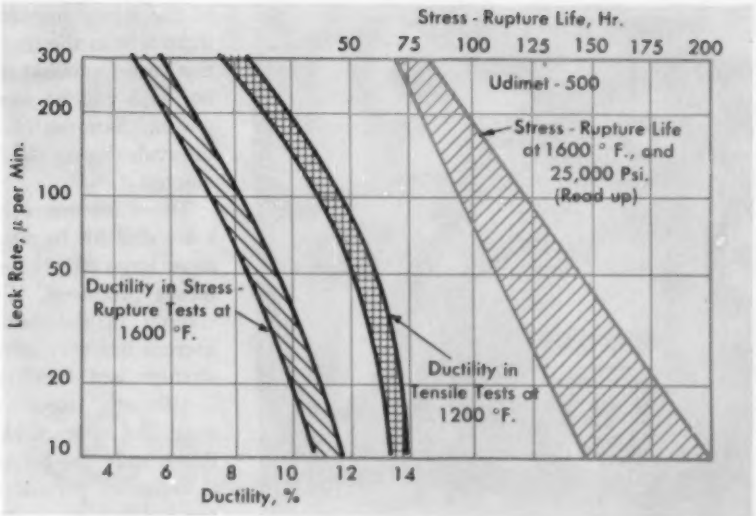

Stress - Rupture Life, Hr.
50 75 100 125 150 175 200
300
200
100
50
20
10
Leak Rate, μ per Min.
Udimet - 500
Stress - Rupture Life at 1600 ° F., and 25,000 Psi. (Read up)
Ductility in Stress - Rupture Tests at 1600 °F.
Ductility in Tensile Tests at 1200 °F.
4 6 8 10 12 14
Ductility, %

Fig. 3 — Influence of Leak Rate of Furnace on High-Temperature Properties of Udimet-500

in the metal produced with leak rates of 100 and 300μ per min. or with the high melting pressure of 1000μ. This decreased to 20 ppm. with the best vacuum obtained. Incomplete data for nitrogen content follow the same pattern although the correlation is not as good.

Gases in the Melting Tank

It has always been recognized that there are gases present in various amounts throughout the melting cycle. What these gases are, and just when they occur, has been the subject of much discussion.

A thorough understanding of this detail is necessary for accurate melting control, and to obtain the necessary information a mass spectrograph was attached to our vacuum melting furnace. It is a monitoring type of instrument with a system that will make analyses over a wide pressure range and at regular intervals. Since the pressures in the melting tank were so low that gas samples did not flow into the analyzing unit, the melting tank was blanked off for 1 min. allowing a build-up of pressure. Analyses were made at approximately 7-min. intervals throughout the heat. Simultaneous recordings of melting pressure were also made.

These curves show some out-gassing at the time the power is turned on. Within 30 min. carbon monoxide from carbon reduction evolves large quantities of gas and the relatively high pressure of 20μ. After about 90 min. the carbon reaction on the first charge has run its course and the second charge of metal is put into the crucible. Again the CO content picks up with this added metal, but since there is not as much new metal this time, it does not rise nearly as high. Again it settles down in about an hour's time to the point that the late additions can be made; for all intents and purposes there is no CO in the system after this.

The nitrogen gas in the furnace remains low throughout the initial melt-down, but with the addition of the second charge it increases to significant levels. This can be traced to the chromium (with 0.06% N_2) added at this time to this particular heat. Similarly, the oxygen content increased after the second charge, which may be the result of the 0.04% oxygen in the chromium metal.

The quantities of these two gases, oxygen and nitrogen, which were being removed from the melt, show a steady decline as the heat progresses up to the time the additions are made. The interesting point is, however, that the additions were made too soon in this heat; the oxygen and nitrogen content had not reached as low a level as they should have, because immediately after the additions were made the amount of free nitrogen coming off rapidly decreased, indicating a quick tie-up with the added titanium, zirconium or aluminum.

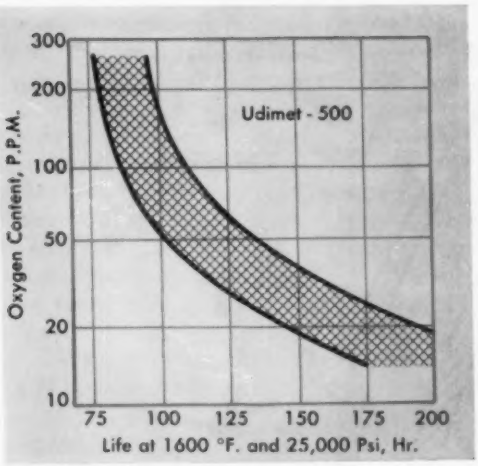


Fig. 4 – Oxygen Content of Udimet-500 Versus Stress-Rupture Life at 1600° F. and 25,000 Psi.

The oxygen and hydrogen content of the furnace increases for a short period (probably due to a little water vapor) and then drops rapidly as it, too, is tied up with the reactive additions. These are highly detrimental reactions, since the addition elements are no longer available in proper form for strengthening. Furthermore the compounds formed are present as very undesirable inclusions.

The hydrogen shown at various periods by the mass spectrograph probably comes from the dissociation of water vapor or from the raw materials. There is considerable amount of this each time a charge is made. There is also a short burst during pouring as a result of out-gassing of the pouring basins or the ingot molds. All this indicates the desirability of thoroughly drying everything before it is used.

Raw Materials

The raw materials used by the vacuum melting industry are primarily in forms of very high purity. This greatly assists in controlling the process. Scrap materials are used under certain conditions in addition to the scrap generated in the plant.

However, full utilization of scrap requires extra processing time. It is often of questionable economic value. The electrolytic metals, as well as other forms of the elements, contain large quantities of gases which (as has been shown by the mass spectrograph) can be handled in the vacuum system, but at the expense of time and often of other operating difficulties.

More attention is beginning to be paid to some of the tramp impurities. For instance, sulphur if present in the melt is not reduced throughout the entire vacuum melting cycle. Neither SO_2 nor H_2S can be found with the mass spectrograph. Samples of the metal taken at regular intervals during the heat show no change in the amount.

There are other impurities which are much more difficult to measure but which apparently have large effects on the properties of the materials produced. For instance, boron or zirconium in the raw materials or from other sources has very decided effects on the rupture strength and ductility of the superalloys.

Although some information is becoming available on trace elements, it seems clear that this is only the beginning.

Ceramics play a very important role; they are holding or controlling the metal from the time a charge is made until the ingot is poured. Like the metals they hold, these materials are subject to the reduction reactions going on throughout the cycle. Because of this, the performance of a given ceramic is usually poorer in vacuum melting than air melting. For the same reason they can contaminate the melt to a greater degree.

The majority of vacuum melters use either magnesia or zirconia linings, usually rammed in place and fired out on a suitable load – such as graphite or a steel can full of metal. In some instances the firing is done in air, although more often under partial vacuum. These linings have a reasonably good life (our experience is an average of 45 heats per lining) although this depends a great deal upon the particular installation and the skill with which the lining is made.

Magnesia linings have the advantage that the product of reduction, magnesium, is readily volatilized and does not change the chemical composition of the heat being produced. Zirconium from zirconia linings remains in the melt; a pickup can be observed in the composition. The advantages of zirconia lie in its somewhat better physical properties as a crucible lining.

We are beginning to learn that there are trace elements in the ceramics which have a significant effect on the properties of the materials produced. In fact it is the same story as for raw materials. Trace elements in ceramics are apparently present as oxides which are reduced and leached out during the melting cycle.

(*Continued on p.* 220)

Progress in Magnesium

*By H. G. WARRINGTON**

Unlimited ore supplies, well-developed reduction and fabrication processes, light weight and other inherent advantages, together with continually improved alloys, foreshadow enlarged consumption for all sorts of machinery in motion, for nuclear reactors, and for consumer goods.
(A general, 17-7; Mg)

WHEN ONE STARTS to appraise the present and prospective situation of any metal such as magnesium, he will try to gather the facts about the amount and availability of the ores, the commercial methods of extracting metal, and finally the important fields into which it has entered and where considerable expansion of tonnage seems probable – all the time with one eye open to similar facts about competitive metals. At the risk of repeating things which are common knowledge to many readers of *Metal Progress*, I will try to summarize some items which will lead to a reasonable projection of the utility of magnesium.

To maintain a perspective, it is worth noting at the outset that the ratio of consumption of the major metals in engineering is of the order of one ton of titanium, ten tons of magnesium and 500 tons aluminum to every 20,000 tons of iron and steel. In comparison with these the metals copper, zinc and lead – used since ancient times –are relatively rare in the earth's crust but easy to recover, and their value varies with supply and demand in long-established uses. Nickel is mined commercially in a very few places; its eventual availability is little known, and it is not yet possible to speculate on the future of this intriguing metal.

As remarked at the outset, three major variables control the growth of a metal's uses: *(a)* the availability of the element, *(b)* its ease of extraction and *(c)* its ability to perform a given function. Magnesium has infinite ore resources; its

*Dominion Magnesium Limited, Toronto.

price will be set by the cost of extraction by the most efficient producer, regardless of supply and demand; hence its value is fairly readily determinable on a cost-versus-performance basis.

Ores – Sea water contains enough magnesium (1300 ppm.) for it to be a source of supply. It is concentrated in sediments. In igneous rocks it increases with depth from less than 1% in granite to 30% in peridotites. The subcrust olivines $(MgFe)_2SiO_4$ contain up to 50% MgO. In fact magnesium was originally obtained from salt beds, and then (during World War II) from sea water and from sedimentary rocks. The last mentioned is of most importance to the Canadian industry.

Some of the pre-Cambrian deposits have been purified by leaching, folded in bed rock and subjected to extremes of temperature and pressure. The dolomite of the Grenville series, exposed by glacial erosion in the Ottawa River valley in Canada, is of this type and has emerged as a crystalline marble, almost chemically pure and of a composition corresponding to the compound $CaCO_3 \cdot MgCO_3$. Calcining this material yields a lime containing 25% magnesium which can be reduced in vacuum to metallic form by ferrosilicon, distilled from the residue, and condensed in the cool end of the retort in one relatively simple operation – the well known Pidgeon process.

Dolomite is by far the most abundant and readily available source of magnesium. Vast beds exist in almost every part of the world. Other workable sedimentary minerals are magnesite (magnesium carbonate), serpentine and the hydrate known as brucite. The last mentioned is a second Canadian source of magnesium.

The importance of the industry to Canada may be gaged by the fact that Canada vies with Norway as the largest exporter of the metal, although the tonnage produced and consumed in the United States and Russia is considerably greater. It is a curious fact that magnesium from any producer in the world, including Canada, can be shipped at lower cost to Tokyo or Hamburg than to Vancouver.

Sea water and dolomite are the principal sources now used in the United States. Igneous rocks are a vast storehouse of magnesium, and since local conditions have so far decided the method of extraction adopted for this metal in different parts of the world, it is not inconceivable that those of the West Coast may ultimately be tapped.

Removing "Crowns", Full of condensed Magnesium, From Retorts in the Pidgeon Ferrosilicon Process at Dominion Magnesium Ltd.'s Plant at Haley, Ont.

Summing up, it may be said that the availability of magnesium exceeds any foreseeable demand, and its low-cost production depends on the development of methods of extraction.

Handling Molten Metal – For over a century, after its isolation by Davy, there was scarcely any real advance in magnesium. Today, when metals so reactive as titanium can be melted and cast, the handling of magnesium is taken for granted. As a matter of fact, industrial interest was small until methods were developed to protect the molten metal from oxygen and nitrogen in the atmosphere.

This was solved by a three-stage fluxing technique. The metal is melted under a very fluid salt mixture which wets the solid metal surfaces until they are molten, and then forms a protective coating over and around the melt. In the second phase, the flux must be stirred in with the metal, almost to an emulsion, to hold in solution or suspension all nonmetallic impurities and carry them down to form a separable sludge. In the final phase the protective flux is thickened to a pasty crust on the surface, so it can be held back by a skimmer without the undesirable salts flowing into the ingot or casting. A recently discovered alternative is to add minute quantities of beryllium to inhibit oxidation.

Such reliable methods of handling magnesium in the foundry have resulted in important structural and mechanical applications. Examples can be quoted of thousands of tons per year consumed in single plants for tractor components, automobile engines or chain-saw parts.

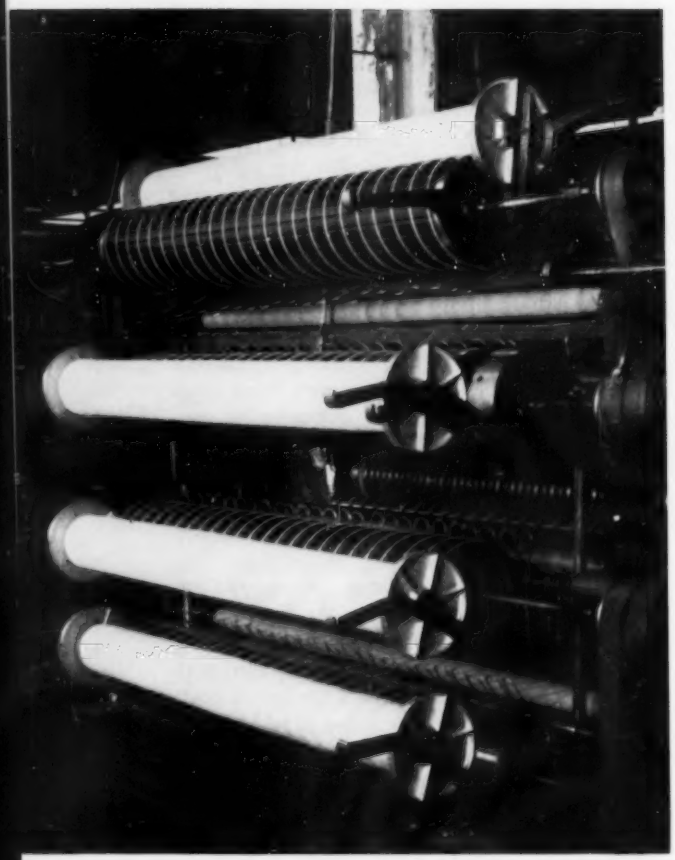
Expanding Usages – In other areas magnesium will grow more or less proportionately to world-wide consumption of all metals. The first of these is the field of alloying. The addition of magnesium to aluminum produces the strong structural alloys on which the aluminum industry is dependent. In amounts of 3% and over it increases the already high corrosion resistance of aluminum, in environments previously denied. Addition of magnesium to a proper cast iron endows it with malleability as cast, and the strength and ductility of ordinary steel.

The other field is that of reduction metallurgy. In the last few years there has been an increasing demand for uranium, beryllium, zirconium and titanium in metallic form. This has consumed a corresponding amount of magnesium of the highest purity as a reducing agent. While all uranium will not be used as metal and some titanium is reduced by sodium, nevertheless, this demand has grown for tens of thousands of tons of magnesium in an operation that did not exist 15 years ago.

Yet another area in which magnesium is tied with the usage of another metal is that of anodic protection. Low-carbon steels will be used for as many years as we can predict for pipelines, distribution pipes, storage tanks, ships and bridges. No matter what type of surface protection is laid over these structures, corrosion eventually destroys them. The only assured prevention is to apply a direct current greater than the local anodic-cathodic currents which cause the rusting. The most economical current in the majority of structures comes from magnesium as an anode and the object to be protected as a cathode in a simulated battery cell in which the corrosive medium is the electrolyte. The metal magnesium is a more convenient source of power for these purposes than the utility companies.

The structural applications of magnesium alloys have been limited up to the last decade by lack of strength at elevated temperatures. At ambient temperatures it is now the next least expensive material to steel for initial cost, and where weight is of any value it is the most economical.

An example may be given in road transport: Trucking companies generally believe that they can pay $1.00 for every pound saved in their rolling stock. A light steel channel 6 ft. long weighing 13 lb. costs about $1.20. The same sized channel in magnesium alloy will cost $2.16 and weighs 3 lb. (In aluminum alloy it would cost $2.25 for 4.5 lb. or titanium $90.00 for 7.5 lb.) On a strength basis a conservative design for a truck body will call for 5 or 6 lb. of magnesium, costing about $4.25, instead of the 13-lb. steel channel. This saves 7 lb. or more, worth $7.00 to the user, who thus has a total saving of almost $4.00. One operator on the Pacific coast claims the only steel in his trailers is in two shafts and the ball bearings! Weight saved in an airplane or its auxiliaries is fantastically valuable; it pyramids into lighter engines and less fuel capacity, and the designer carefully appraises each part on a strength-weight basis. The wrought and heat treated strong aluminum alloys are nearly twice as strong as their best magnesium counterparts and weigh only two-thirds more. Consequently they get the preference except in special places where the added thickness of the magnesium part lends necessary added stiffness against buckling, or in places where the incomparable machinability of mag-



Magnesium Jack-Spools Are Easy to Handle in a Weaving Mill

nesium is an important factor. (It has been well said that no machine has ever been built which can cut too fast for magnesium.)

A different set of circumstances exists in casting alloys. On a strength-weight basis, magnesium is superior and hence we find that most of the magnesium in aircraft is in heat treated alloy castings.

The magnesium alloys for use at normal temperatures are those containing from 2 to 10% aluminum, with about 1% zinc and a minor addition of manganese. The benefits of additions of the rare earth metals (misch metal) have been known for 25 years, but have been recently emphasized by the need for creep resisting alloys for gas turbine engines or in heated portions of the fuselage near the engine or the exhaust. These alloys contain nominally 3% misch metal, and are grain refined with zirconium. This has warranted applications in positions where they reach as much as 600° F., although the low-temperature properties are not so attractive.

A further notable advance in this same direction has been made by adding up to 4% thorium, in combination with appropriate amounts of zinc, zirconium and manganese. As indicated by Dr. Leontis's article in *Metal Progress* in August of this year, p. 97, such alloying has now extended magnesium alloys to the position where they give the highest strength-weight ratio of all commercial constructional metals up to 800° F. The thorium-containing alloys also have attractive room-temperature properties.

Based on tensile properties alone it can be argued that oxidation resistant steels of equal strength-weight ratios are regularly produced. On the other hand, the magnesium alloy is four times as bulky for the same weight, which means that members do not need to be paper-thin and production can go forward in normal equipment. Magnesium also has a considerably higher thermal conductivity, and a high "damage resistance" factor which allows the designer freedom to develop the most favorable section.

In the field of nuclear energy the high purity, strength and low neutron absorption capacity of magnesium give it a place in structural applications in addition to its use as a reducing agent for uranium. The excellent behavior of the magnesium alloy sheaths in the Calder Hall reactor (*Metal Progress*, July 1957, p. 67) shows that damage from radiation is minor and the life of the elements has exceeded expectations. The fact that strong alloys can be produced using elements such as zirconium, of favorable characteristics and free from dangerous "daughters" after radiation, gives magnesium a wide field in reactors operating at moderate temperatures.

Summary – Magnesium today has reached a turning point in its history. The applications cited have arrived because each one needed a material to perform a given function – to get maximum life from a pipeline because of replacement cost, for the best engine life and road performance of the Volkswagen car, or the highest pay-load for the lowest tax-load on a truck. Almost all grain on the Great Lakes is handled with magnesium scoops and tackle blocks at the demand of labor unions for the lightest equipment. The list increases each year, and also we begin to see the housewife using magnesium step-ladders, the hotel porter a finger-light baggage truck, and the neighbor cleaning his walks with a featherweight snow pusher. These are the important people – the ones who bring it home!

Advances in Nondestructive Test Methods

STAFF REPORT

Five individual tests are made on each tube accepted for a nuclear reactor – visual, fluorescent penetrant, X-ray, eddy current, ultrasonic. Latest devices in these fields are outlined, together with "Photostress", where surface stresses are estimated from the reflections of polarized light from a plastic sheet cemented to the part. (S-13, 1-3)

NINE chapters in Dixie cooperate effectively in holding annually a Southern Metals Conference, this year (May) in Jacksonville, Fla. All the eight meetings had a single slogan, "New Horizons". One session was devoted to five papers describing newly developed equipment and methods for testing nondestructively and measuring electronically. Before summarizing them, two general comments are in order. The first is that most of the speakers represented equipment manufacturers and had of course a good deal to say about the virtues of the various instruments, whereas a better-balanced program would have had other speakers – users who could vouch for selectivity and accuracy in performance. The other comment would be that the arrangements committee-men must have been experts on automation and used invisible electronic gadgets to operate these technical meetings for the greatest convenience and interest of their guests.

Ultrasonics – According to C. E. Betz of Magnaflux Corp., Chicago, the use of ultrasonics has become widespread, first by the resonance method for determining the thickness and soundness of thin metal sections. Accurate thickness measurements may be made in the range from 0.01 to 2.00 in. Laminations, voids, inclusions, lack of bond in brazed or clad materials, and decrease in thickness due to corrosion may also be detected. Instrumentation has also been greatly improved and simplified. Today a small portable instrument weighing 17 lb. can measure thickness up to 4 in. and report on a direct-reading scale.

Ultrasonics equipment has also undergone considerable improvement in the field of pulse reflection. Addition of the "B-scan", and refined immersion techniques, have greatly extended the utility of this method to the inspection of large forged and extruded shapes, particularly in the airframe industry.

Angle crystals which generate shear waves are being applied to the inspection of welds. They may also locate surface discontinuities. New types of crystals for transducers, such as barium titanate and lithium sulphate instead of quartz, are also being investigated.

(COMMENT – Especially would it have been valuable to the auditors to have received a level-headed discussion of *interpretation* of ultrasonic indications. This reporter remembers that two or three years ago, General Electric engineers analyzed a great mass of such data on hundreds of large rotors for electrical generators, combined with destructive tests on forgings rejected after ultrasonic inspection, and devised a "go, no-go" chart whereby forgings free of cracks could be selected.* Yet a bad accident occurred a year or so ago to a rotor which by this criterion should have been safe.)

*See *Metal Progress*, February 1956, p. 57

End Dome of Shippingport Reactor. (Courtesy Combustion Engineering Co.)

Eddy Currents – Mr. Betz also mentioned a large variety of electronic testing methods based on eddy-current measurements, attributing much of this development to the work of Friedrich Forster of Germany. The instruments mainly measure the electrical variations in a coil carrying an alternating current of appropriate frequency, placed near the metal object.

This testing method is said to have many uses in America. Some of these are *(a)* determination of electrical conductivity of metals and alloys, *(b)* detection of hardness of aluminum alloys within plus or minus 4 points on the Rockwell B-scale, *(c)* thickness of metal films, electroplates and cladding.

Similar equipment can find surface defects in wire, bars, and tubing; here the material being tested is passed through coils which are fed with oscillating current of a frequency adapted to the material. Discontinuities are indicated on a cathode-ray screen. Sometimes two variables are measured at once, such as surface defects and dimensional variations. Other electronic equipment can detect the degree and direction of grain orientation in transformer sheets, Young's modulus of metallic alloys, and damping capacity.

Magnetic particle inspection ("Magnaflux") has been extended into new fields through the development of automatic equipment, according to Mr. Betz. Practices for inspecting tube rounds, seamless tubes, seam welded pipe, honeycomb sandwich construction, and other assemblies were described.

Fluoroscopy – Alexander L. Gobus of North American Phillips Co., New York, briefly reviewed developments in the field of X-ray fluoroscopy. The object here is to decrease costs by eliminating photographic film. This requires a screen of high brightness combined with industrial X-ray equipment especially designed for the fluoroscope and with intensity of X-ray adjustable to the needs of the specific application. A contribution to the solution of these problems is the new Phillips image intensifier which contains a fluoroscopic screen of unexampled brightness. This intensifier consists of an X-ray target, and the phosphor with the object half way between; this gives an X-ray magnification of two diameters. The image intensifier contains a fine grained phosphor, backed with a metal coating which converts visible radiation to electrons. Through the influence of high voltage, the electrons emitted from the photo-cathode are accelerated, resulting in a thousand-fold gain in brightness at the fine grained fluorescent screen.

Mr. Gobus gave complete details of the special components in this equipment in its pilot stages at Phillips' plants in Holland. He projected photographs of installations for inspecting longitudinal welds in large diameter pipe with ½-in. wall. Rate of inspection was 10 ft. per min., which approximates the normal welding rate. The equipment included a viewer inside the pipe and a television screen which the inspector watched – an arrangement similar to the one illustrated in *Metal Progress* for July. One worry persists: Will this or will it not affect the inspectors' viewing habits for commercial TV?

Photo-Elastic Indicators – "Photostress", a photo-elastic experimental stress analysis technique was described by F. Zandman of Tatnall Measuring Systems of Philadelphia. The piece to be stress-analyzed is coated with a clear plastic that becomes doubly refractive when stressed, whereupon the over-all distribution of surface strains appears under polarized light as black and color fringes in the plastic coating. This avoids making plastic models of stressed objects; it can also be applied locally to any large structure to determine strains at critical sections. It differs from usual photo-elastic techniques in that a transparent plastic (either

(*Continued on p.* 222)

ARISTOLOY STEELS

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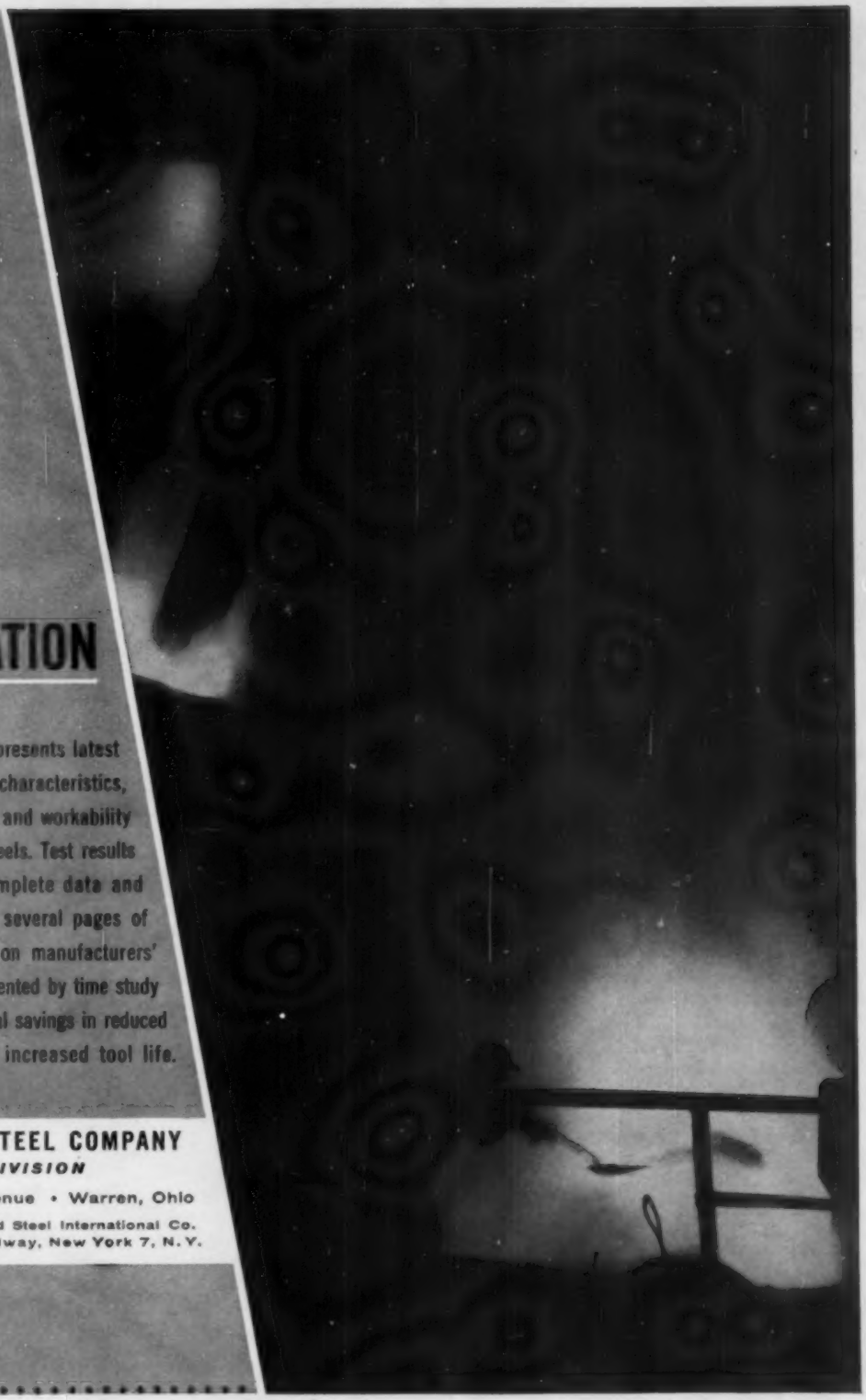

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Why Be a Metallurgist?

NORMAN, OKLA.

The letter by Student Allen Alchian on p. 120 raises some interesting questions, particularly in economics. Editor Thum's reply is a cogent exposition of "why be a metallurgist" from the standpoint of economic as well as less tangible rewards. Some observations based on my own experience in both academic and industrial fields may be a helpful supplement.

First, let's look at some characteristics of the professions. A professional person possesses a higher intelligence level, more resourcefulness and ingenuity, better ability to understand relationships than is found in men in the trades. His work is more mental than physical. He is a person with highly individualistic talents. The value of his work is more difficult to establish in concrete terms because he is continually dealing with ideas and concepts. The professional thinks many hours for which he is not paid. He asks for a chance to do a larger job and to earn the right to manage more extensive responsibilities. He knows that the fruits of his work are much greater than if he were making electrical connections, sawing wood or plastering laths. He has pride in his work that few craftsmen take in theirs.

Professionals invest from four to eight years of their lifetime in their training in order to have the chance to try for the big job. They are men with vision, men with developing judgment and firm convictions. Metallurgy is one field in the professions. It happens to be one of the fields for which there is the greatest opportunity open to young men.

What the professional doesn't want is a bargaining agent that whittles his ability to the level of the least competent in the trade. The American Society for Metals is a professional society. There are dozens of this type of society, many of them working closely with one another. There is no jurisdiction as you will find in the mass labor organization. Rather it is a grouping of scientific men and practical engineers who put time and energy into a common cause. Here you find the mingling of academic men and industrial men. These people are not concerned with the short-term cycle of a labor market so much as they are with the continuing supply of intelligent and competent recruits that will assure fullest service to mankind.

I am not sure whether I am the college teacher you referred to. If I am, let me advise you that I spent 13 years in industrial employment and during World War II was chief chemist on a hundred million dollar operation. I have voluntarily taken a very considerable reduction in salary to become a teacher but I have gained a very marked increase in prestige. I enjoy working with and teaching young people. It has been a cardinal point that I do not beat the drums just to pull individuals into a scientific field. Whenever I run across a young man who does not have the mental ability for college work, but with ability enough to have a useful, happy and rewarding life in one of the semi-professional crafts, I do not hesitate to encourage him to choose one of those fields *after* he has looked at all the factors. I am a little impatient with young people who sell themselves short by looking for the softest course of study; many never realize what their potentialities are.

You are implying that we college teachers feel that we have to have many people come to college to fill our classes so that we don't have to pump gas or something. Frankly there are many young men who come to college who do not deserve that privilege. Some of them have kicked the gong around and goofed off to where they don't deserve to have any future opportunity until they have faced up to personal responsibility. I am not concerned about having empty classrooms. All of the forces of civilization are working in the other direction. We have to try to teach individuals who weigh us down by sheer indifference and laziness to the point that we can't do what we should in order to develop those who deserve more attention. Consequently, I reject your inferred motivation of my interest in this area. My concern is to fill useful minds, not fill classroom chairs.

There is room for many more good young men in the sciences and in engineering; it is a choice that should be based on personal interest and special aptitudes. The prospect of a 40-year period of useful and interesting life should outweigh any temporary wage-scale advantage. There is room in each of the professions for good young men who want to be individuals and want an opportunity to advance. There is not room for the man who wants to learn the job in a month and then take no further responsibility for personal development. I believe that probably the greatest opportunity for a young person now lies in metallurgy.

HORACE H. BLISS
Chairman
Oklahoma Science Service
University of Oklahoma

(*More correspondence on p.* 148)

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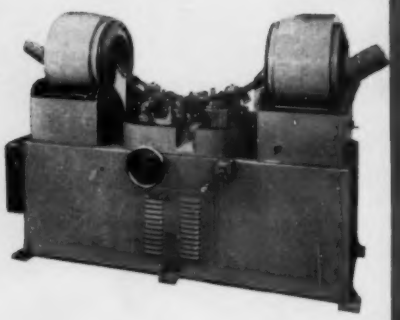

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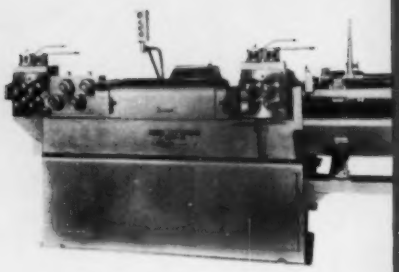

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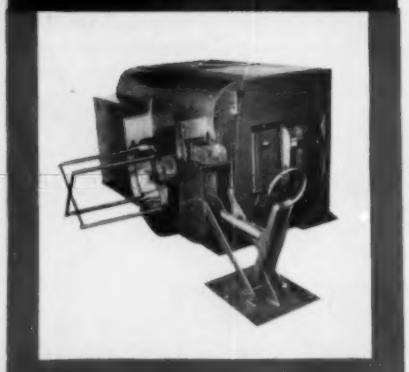

A new, modern bull block for producing finished wire from ¼" to ¾" diameter. Speeds from 100 ft. to 400 ft. per minute. Available in a range of from 40 to 100 H. P. A streamlined piece of equipment with a production capacity far in excess of competitive equipment.

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Musical Metallurgy

TORONTO

I noted with interest the digest in the August 1957 issue of *Metal Progress* on "Musical Metallurgy" — in particular, the paragraph on the making of bells. Could it be a printer's error, an error on the part of the precis writer, or have they really started making bells in Birmingham from an alloy of 80% tin, 20% lead?

I am particularly intrigued by this since not only was I born in Birmingham myself, but my late father was also one of the foremost campanologists in the British Isles. (For the uninitiated, a campanologist is a person versed in the art of change ringing on church or other bells.)

Seriously, an error has been committed somewhere since the standard mixture used for the manufacture of bells is 78% copper, 22% tin, occasionally modified with additions of zinc, iron, nickel or antimony.

F. C. DOWDING
Chief Metallurgist
Lucas-Rotax Limited

EDITOR'S NOTE — Mr. Dowding is correct. The error originated in the digest, and was not caught in the editorial office. E. E. T.

Kelly-Bessemer Process

CHICAGO

The article on p. 77 of the August issue of *Metal Progress* is interesting — and completely misleading. If Mr. Weiss regards the Kelly-Bessemer process as having been anticipated by a furnace that uses the blast from a bellows, then, surely, he should at least go back to Theophilus (somewhere around 1000 or 1100 A.D.), who describes a furnace for bronze bellfounding that is like Réaumur's except for the ingenious tilting mechanism; and perhaps he should seek the first use of bellows anywhere. Réaumur's furnace was a cupola, not a converter. It used charcoal as a fuel and produced little change in the composition of the metal that was melted. The product was *not* steel, but white cast iron, which was poured into sand molds and subsequently annealed for malleabilization.

And why bring Swedenborg's name into the story? He merely

Need special-purpose wire or steel?

Whether it's manufacturing special wire and steel to your specifications, or working with your engineers to develop new types to solve new problems, you can always count on National-Standard for something extra . . . in quality control . . . in product uniformity . . . and in service! Not just an idle boast. We've been doing it that way for over 50 years . . . and would like very much to prove it to *you*.

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High Carbon Steel Wire . . Minimum Rope Diameter .008"
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Kelly-Bessemer . . .

had the illustration re-engraved, and translated its description into Latin. The furnace is Réaumur's alone. This very picture, copied from the original engraving in the 1722 edition, was used on the dust jacket of Mrs. Sisco's 1956 English translation of Réaumur's work.

Swedenborg's three - volume "Opera Philosophica et Mineralia" gives a useful picture of Swedish practice in the 1730's, but a good deal of the metallurgical information is merely compiled from earlier publications, with meticulous credit. It would be nice to see *de Ferro* put into English, but it is available in Bouchu's French (1762 and later). An English version would change the history of technology a very great deal less than its author's mystical writings have affected religion. Personally I would much rather see an English translation made of the "Försöck till Järnets Historia" written by Swendenborg's compatriot Sven Rinman in 1782. This has the stamp of originality on every page and gives a fine detailed picture of the science and technology of iron and steel at an extremely critical stage in their development.

CYRIL STANLEY SMITH
Institute for the Study of Metals
University of Chicago

Who Makes High-Purity Metals?

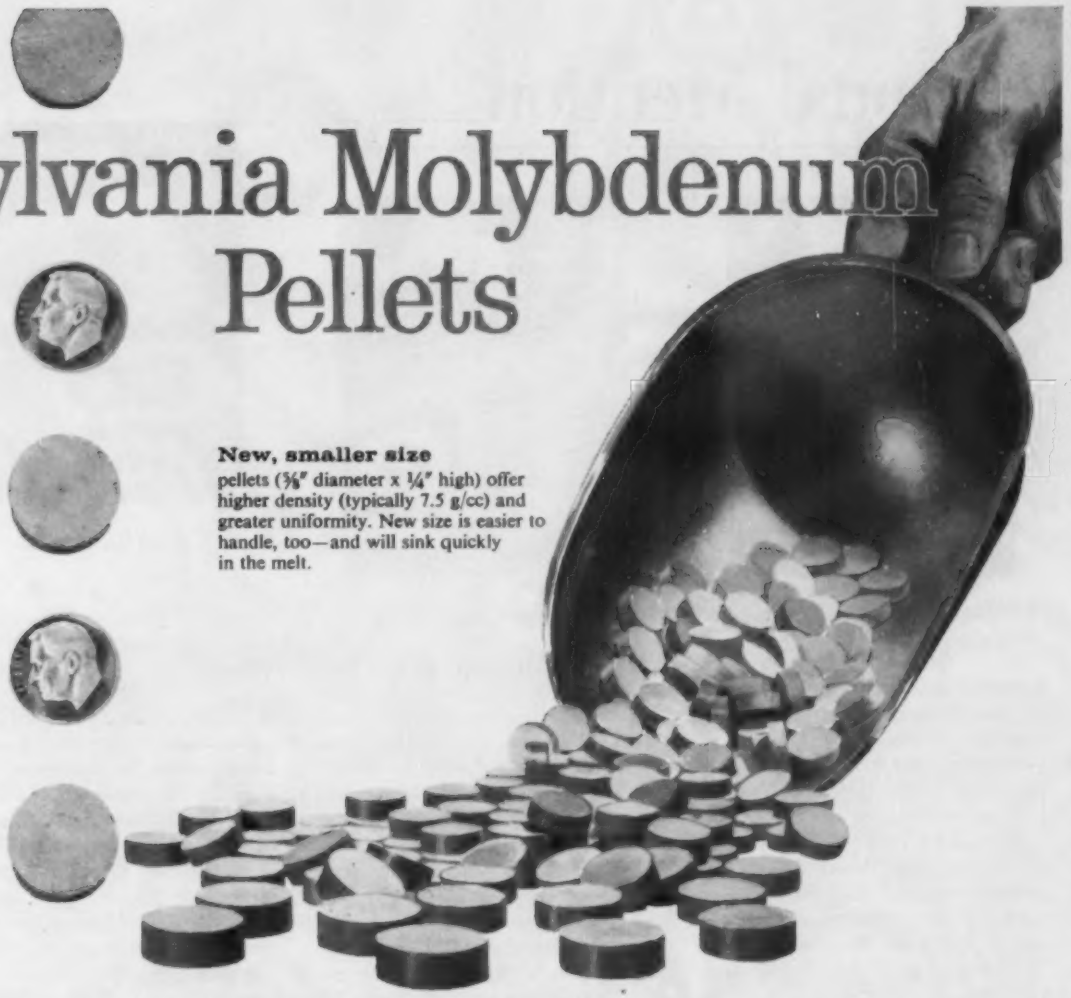
AMES, IOWA

Frequently, researches financed by the U.S. Atomic Energy Commission require considerable quantities of metals of highest purity, and just as frequently we do not know where the metal has been or is being produced in commercial or pilot-plant quantities. Our requirements run from the common metals such as zinc to the rare ones such as scandium.

I would welcome correspondence on this matter, either from the producers of high-purity metal anywhere, or from researchers who have faced a similar problem and found a suitable source.

HARLEY A. WILHELM
Associate Director
A.E.C. Metallurgical Laboratory

Sylvania Molybdenum Pellets



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pellets (⅜" diameter x ¼" high) offer higher density (typically 7.5 g/cc) and greater uniformity. New size is easier to handle, too—and will sink quickly in the melt.

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Personal Mention

George Sachs

Three German institutions have honored GEORGE SACHS, professor of metallurgical engineering and associate director of the Syracuse University Research Institute, for his many contributions to science and engineering.

Dr. Sachs was awarded the Gauss-medal by the Braunschweigitche Wissenschaftliche Gesellschaft, an academy for engineers, physicists and chemists of the Institutes of Technology in Braunschweig and Clausthal.

The highest award of the Gesellschaft für Metallkunde (the German Society of Metals), the Heyn Medal, was also presented to him. Both awards mention his outstanding achievements in the metallurgical field, including the mechanical and X-ray stress measurement methods developed by him.

In addition to these medals, Dr. Sachs was awarded an honorary degree of Doctor of Engineering from the Bergakademie of Clausthal, the only university in West Germany devoted to mining and metallurgy.

Since coming to this country from Germany in 1936, he has held various positions in the metallurgical field, including nearly ten years at Case Institute of Technology as a professor and director of the Metals Research Laboratory, and more recently several years as vice-president of Horizons, Inc., in Cleveland. Dr. Sachs is also a consultant for several companies here and in Germany.

Harry J. Huester

HARRY J. HUESTER has been transferred to the Naval Air Material Center, Aeronautical Structures Laboratory, at the Philadelphia Naval Base, formerly the Naval Aircraft Factory. With this move, Comdr. Huester returns to the base where he began his naval aviation career nearly 40 years ago.

In 1918, he was first assigned to the metallurgical laboratory of the Naval Aircraft Factory, the first such installation in naval aviation research and development. After 11 years at this base, he was transferred to the Bureau of Aeronautics in Washington, D.C., as a materials engineer and remained with the Bureau on various assignments in this country and abroad for over 20 years. In 1951, he was assigned as technical director of the Aviation Supply Office in Philadelphia. Two years later he was sent to the Naval Air Station in Jacksonville, Fla., as aeronautical engineering officer of the overhaul and repair department, fleet aircraft and technical training support.

While stationed in Jacksonville, Comdr. Huester, then a 30-year member of A.S.M., found there were no chapters located nearby and immediately began efforts to organize the first chapter in Florida. He served as first chairman of the Jacksonville Chapter and last May acted as chairman of the Southern Metals Conference held in Jacksonville, Fla.

Allen G. Hotchkiss

ALLEN G. HOTCHKISS, manager of engineering-special furnace heat processing equipment, of the industrial heating department, General Electric Co., Shelbyville, Ind., has received the Trinks Industrial Heating Award for his pioneering developments in protective atmospheres. His citation includes mention of his development of exothermic and Neutralene generators at G.E. and the introduction of exothermic gas in copper brazing.

Mr. Hotchkiss's entire professional career has been spent with General Electric. After his graduation from Kansas State College in 1926, he joined G.E.'s engineering test program, and after two years in various divisions, he was assigned as an engineer in the industrial heating department, engaged in development work on furnaces. In 1931 he became one of the first to work with furnace atmospheres and equipment, and continued in this field until he joined the Armed Forces in 1942. After the war, he returned to General Electric and was soon named technical leader for the department's furnace and associated equipment section. He has held his present position since 1954, and recently has been acting as consultant for the department's furnace engineering section.

Norbert Kopchinski is presently a consulting engineer for Harper Engineering Co., Santa Monica, Calif., on field assignment at the University of California's radiation laboratory in Livermore, Calif.

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Personals . . .

Bennett Bovarnick, supervisory physical metallurgist of the Gen. Thomas J. Rodman Laboratory, Watertown Arsenal, Watertown, Mass., has been awarded the Secretary of the Army's Research and Study Fellowship. As a recipient of this award, Dr. Bovarnick is entitled to six months study at California Institute of Technology, where he will work on a project to discriminate reliably, by nondestructive research technology, between levels of quality of sintered metal materials. This fellowship is awarded not only for past achievement but for the proposal of a creative plan for study and research.

Joseph E. Foster and **James J. Kubbs** have joined the editorial staff of the American Society for Metals as associate editors of Metals Handbook. Mr. Foster was formerly asistant to the technical director of the American Foundrymen's Society, while Mr. Kubbs was chief metallurgist with the Jeffrey Mfg. Co., Columbus, Ohio. In addition to more than ten years with the Foundrymen's Society, Foster's metallurgical background includes positions on the technical staff of International Harvester Co., Rock Island Arsenal and Western Cartridge Co. Prior to joining Jeffrey Mfg. in 1950, Kubbs was connected with National Smelting Co., Vlchek Tool Co. and Modern Steel Treating Co. in Cleveland.

Fred Louis Siegrist has been appointed training supervisor for the rapidly expanding Metals Engineering Institute of the American Society for Metals. Until taking over his new assignment, Mr. Siegrist was a staff metallurgist for the Aluminum Co. of America, concerned with development work and quality control of extrusions. He has also been affiliated with the Wright Aeronautical Div. of Curtiss Wright Corp., Wood-Ridge, N.J., and Westinghouse Electric Corp.

Lee E. Dillenbeck has joined the staff of the Bettis plant of the atomic power research laboratory, Westinghouse Electric Corp., Pittsburgh. Mr. Dillenbeck will be engaged in engineering and development work on nuclear cores.

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Sandusky Centrifugal Castings offer you 4 Important Advantages

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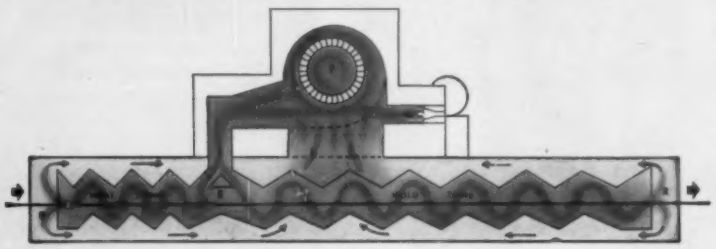
Industrial's "Circ-Air" tempering furnace is the most efficient heating machine ever designed.

The turbulent recirculation of hot gases through and around the work insures maximum and uniform heat transfer. Proper channeling of the hot gases to the work prevents wasteful dissipation of heat; and puts heat where it is needed — on the work.

A "Circ-Air" processing 2000 lbs. per hour at 1300° F., holding ±5° F., forces 14,500 C. F. M. of hot gases through the work. "Circ-Air" heating is recirculation at its best.

The continuous "Circ-Air" is suitable for heating steel, brass, aluminum and cast iron at temperatures up to 1450° F.



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The work is carried on a continuous conveyor. Loading can vary; ¼" bolts are densely loaded up to 3" deep. Less dense loading may be 20" deep. A 3' x 21' "Circ-Air" tempers over 2000 lbs. per hour.

Hot gases from the combustion chamber "C" and recirculated gases returning from the work chamber mix in the fan area "F." Entering the heating area through "T" at control temperature, balanced heat is directed to the charge and discharge ends, and is returned to the mixing chamber. The continuous V construction of the metal liner forces the hot gases up and down through the load at high velocity. The hot gases in the heating zone flow counter to the work. Heat transfer is rapid. Equilibrium is reached at point "E", and ±5° F. is held the length of the holding zone. Heating is without temperature head.

"Circ-Air" furnaces have been built in widths up to 108 inches, in lengths up to 165 feet, for temperatures from 250 to 1450° F., and capacities from 200 to 16,000 lbs. per hour. *Send for Bulletin 13-A*

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Personals . . .

Lewis P. Wilson, until recently chief metallurgist for the U.S. Defense Corp., St. Louis, Mo., a subsidiary of Olin Mathieson Chemical Corp., is now a process engineer for the Sandia Corp., Albuquerque, N.M. Before moving to St. Louis, he was a research metallurgist at the Olin Mathieson home plant in East Alton, Ill.

Stanley M. Norwood, vice-president of the Electro Metallurgical Co., New York, a division of Union Carbide Corp., has been assigned additional responsibilities as assistant to the president of the company. Mr. Norwood has been associated with Union Carbide since its formation in 1917, and since 1927 has devoted his time to sales and technical development with the Electromet division.

Emil A. Kovacevich has accepted a position as metallurgist concerned with high temperature nuclear applications with the AiResearch Mfg. Co. of Arizona, Phoenix, Ariz. A graduate of the Montana School of Mines, Mr. Kovacevich was formerly a metallurgist at Oak Ridge National Laboratories, Oak Ridge, Tenn., a division of Union Carbide Nuclear Co.

Herbert E. Edlund has been appointed president of the Air-Tronics Engineering Corp., Miami, Fla. His duties will be to coordinate and formulate all design, engineering and sales activities.

Eric M. P. Caunce has been promoted from chief chemist and metallurgist with the Ford Motor Co. of Canada, Ltd., to manager of the chemical and metallurgical department manufacturing staff of the company.

Howard R. Palmer has transferred from the National Lead Co., Sayreville, N.J., to the development engineering department of Titanium Metals Corp. of America, Henderson, Nev.

Rollin E. Hook is on active duty with the U.S. Air Force, stationed at Wright-Patterson Air Force Base, Dayton, Ohio, in the metallurgy branch of the aeronautical research laboratory, Wright Air Development Center.

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Molten aluminum can't wet, can't harm the precision-formed parts shown here. These parts and fittings for aluminum die-casting and direct-chill castings are all made of REFRAX® silicon-nitride-bonded silicon carbide. They are Carborundum's answer to the need for a material that can be formed into intricate parts with outstanding corrosion resistance far above normal melting temperatures. REFRAX shapes are solving many problems in aluminum holding furnaces and aluminum alloying furnaces (including reverberatory and induction).

Consider the value of these other properties in your operation: Tolerances of ±.0005 in./in.; a modulus of rupture of 5600 psi at 2450°F (even the best heat resistant alloy melts below this temperature); and high heat conductivity that approaches that of chrome-nickel steel. Write today for product bulletin and technical articles on REFRAX materials. ***Refractories Division, The Carborundum Company, Perth Amboy, New Jersey, Dept. MM107.***

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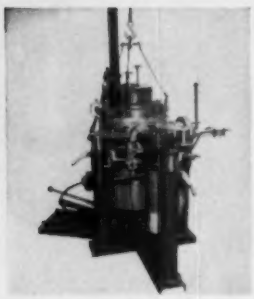
From laboratory to full production *you'll* find *your* answers to problems in Vacuum Metallurgy in



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KINNEY Pumps comprise the most extensive selection of sizes and types in the entire High Vacuum field. From single-stage Simplex and Duplex (with ultimate pressures of 10 microns, McLeod), and two-stage Compounds (producing pressures to 0.2 micron, McLeod), to the famous KINNEY Mechanical Booster Pumps providing ultimate pressures of 0.2 micron, McLeod or better, here is the ideal equipment for *you!*

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Personals . . .

Morton M. Jenkins has joined the A. M. Byers Co., Pittsburgh, as steel sales metallurgist, in line with the company's expansion of specialty steel business. Before coming to Byers, Mr. Jenkins was chief metallurgist with Pittsburgh Forgings Co.

James M. Zimmer has left the Aircraft Gas Turbine Div. of General Electric Co., Evendale, Ohio, to become a staff metallurgist in the research and development laboratory of Crucible Steel Co. of America, Pittsburgh.

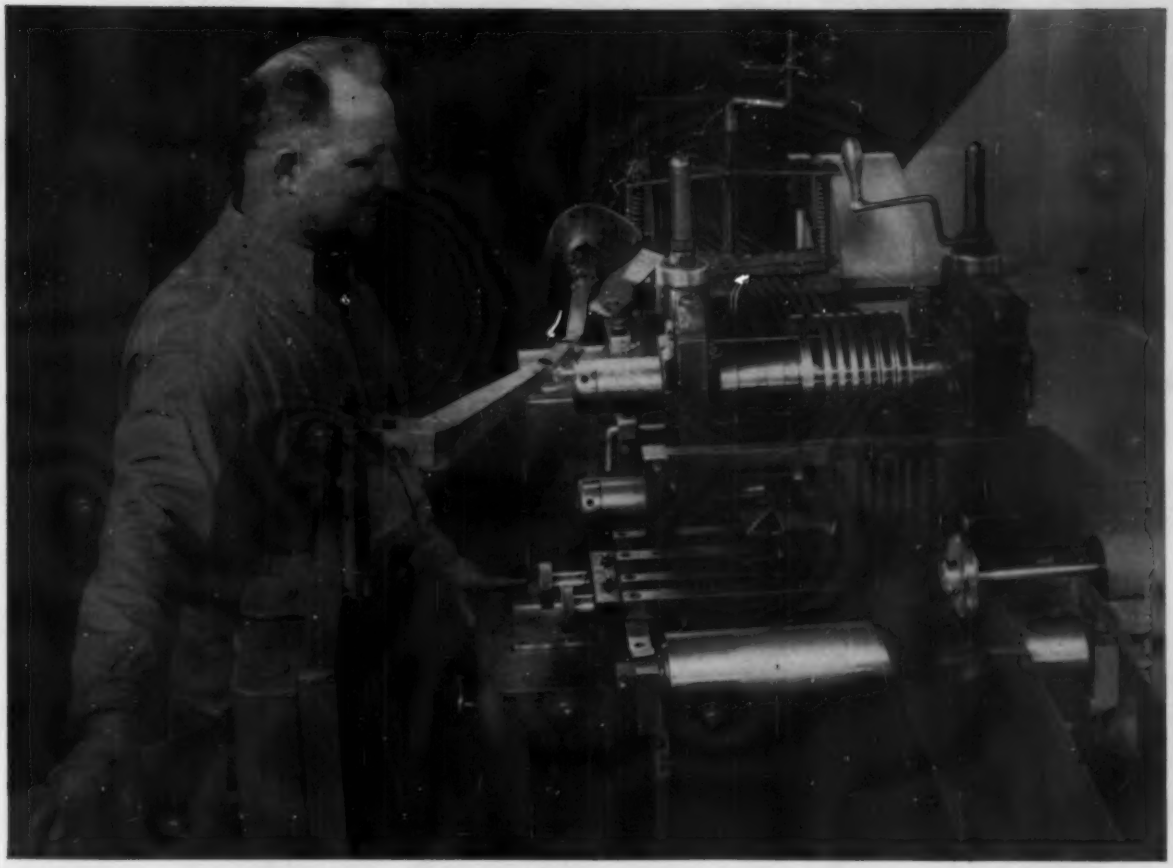
Thomas E. Clagett is the newly appointed Detroit district sales engineer for Wickes Machine Tool Div., Wickes Corp., Saginaw, Mich. Prior to his appointment, Mr. Clagett served the division in an engineering and sales capacity.

Robert L. Reed has been appointed regional manager of the Pittsburgh sales region for the Electro Metallurgical Co., New York, a division of Union Carbide Corp. Prior to his new appointment, Mr. Reed was acting regional manager of the Pittsburgh region, which includes the Pittsburgh and Cleveland districts.

Hugh Trumbull has been named plant manager of the Solar Steel Corp.'s Worcester, Mass., plant. Mr. Trumbull, who has been with the company for seven years, was New England sales manager for Solar until his promotion.

W. Lee Williams has been selected to superintend the metals division of a newly established metallurgy department at the U.S. Naval Engineering Experiment Station, Annapolis, Md. The metallurgy department is the first of four major specialized departments being established in the reorganization of the Station's technical laboratories. Mr. Williams was assigned to the Station in 1942 as a lieutenant in the Naval Reserve and after his discharge in 1946 remained in a civilian capacity. He last headed the physical metallurgy branch of the now disbanded metallurgical laboratory.

John R. Rink has accepted a position as materials engineer with Minneapolis Honeywell Aero Div. in St. Petersburg, Fla.



Yoder Slitters Supply Varied Strip Widths for Tinnerman *Speed Nuts*®

Tinnerman Products, Inc., Cleveland, Ohio, produces more than 10,000 different shapes and sizes of "SPEED NUT" brand fasteners for industry . . . many of them to special specifications.

To do this, Tinnerman uses slit steel strands ranging in width from ⅛" to 7½". To carry an inventory of the many strip widths required to meet normal and unusual demands would be almost impossible.

Tinnerman overcomes these inventory and supply problems by doing their own slitting on two Yoder slitters. This enables them to supply the plant with any strip size required from a relatively small inventory of 6" and 9" width purchased coils. In slitting narrow strands, such as these from small coils, a Yoder slitter may be profitable on a production as low as 25 tons per month.

Here is a fine example of how a small investment in Yoder slitting equipment greatly simplifies and speeds production while effecting important operating economies.

The saving made in time alone, reflects in better customer service through faster completion and delivery of finished products.

If your steel strip or sheet slitting requirements are as low as 100 tons per month or even less, a medium size Yoder slitter can be a very profitable investment for you. The Yoder line includes units of every size and capacity . . . of the most advanced engineering design. Send for the Yoder Slitter Book—a comprehensive text on the mechanics and economics of slitters and slitting line operation, with time studies, cost analyses and other valuable data. Write to:

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Gardsman PYROMETRIC CONTROLLERS

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Model JP PROPORTIONING CONTROLLER

New Accuracy for Most Uses

This modestly priced instrument automatically adjusts the ratio of power "on" and "off" over a time-cycle to maintain desired temperature. After heating to the "proportioning band" (1% of scale range) it "anticipates" temperature change of load, correcting for lag in both heating and cooling.

Model JS STEPLESS CONTROLLER

Exclusive Design gives closer Control than otherwise possible

This unique instrument employs no relay, ends dependence on any form of "on-off". It modulates input through infinite stages according to demand, maintaining a desired temperature *precisely*. It also indicates true temperature at all times, offers dual pilot-lights and other features.

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Personals . . .

Angelo V. Alessandria, who received his master's degree in metallurgical engineering at the Polytechnic Institute of Brooklyn, is now affiliated with the Arabian American Oil Co. as a corrosion engineer in the New York office. Mr. Alessandria is also secretary of the New York Chapter.

David Zucker has joined the Bettis plant of the atomic power research laboratory which Westinghouse Electric Corp. operates in Pittsburgh for the U.S. Atomic Energy Commission. Mr. Zucker is a performing engineer, working with the nuclear core section.

E. R. Johnson, operating vice-president of Republic Steel Corp., and **Dr. Harold K. York,** professor at New York University and director of the research division of the University's college of engineering, are directors of the newly organized R-N Corp., New York, owned equally by the National Lead Co. and Republic Steel Corp. The company controls a direct reduction process which can be licensed by other companies.

H. M. Boyle is the new manager of the claims department of Sharon Steel Corp., Sharon, Pa. Mr. Boyle, who began his career with Sharon in 1940, has served the company in various capacities, including that of contact metallurgist in customer service.

Harold W. Miller, head of the engineering department of the Carpenter Steel Co., Reading, Pa., has been given the further responsibility of coordinating all engineering functions, including electrical and mechanical maintenance, for the company. Mr. Miller started his career with Carpenter as a chemist 20 years ago and rose to chief plant engineer in 1954.

Harold C. Sebring has become a member of the advanced research and development division of the International Business Machines Computer Laboratories, Oswego, N.Y., where he will act as staff engineer. Mr. Sebring was formerly stationed in Washington, D.C. as a senior technical intelligence specialist for the U.S. Air Force.

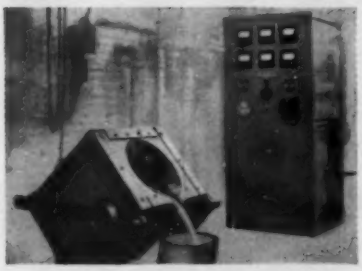
(*Continued on page* 171)

Metal Progress

Bulletin Board...

The Buyers Guide For Metals Engineers

Inducto



THE INDUCTION MELTING FURNACE WITH PRECISION CONTROL

Here is induction metal melting equipment at its best!

NEW FURNACE DESIGN . . . Sturdy, welded construction eliminates distortion and increases lining life.

NEW COMPACT CONTROL . . . Totally enclosed panels include built-in capacitor bank, selector switches and high frequency transformer. Compact design for efficient operation and shipped completely assembled.

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INDUCTOTHERM CORPORATION

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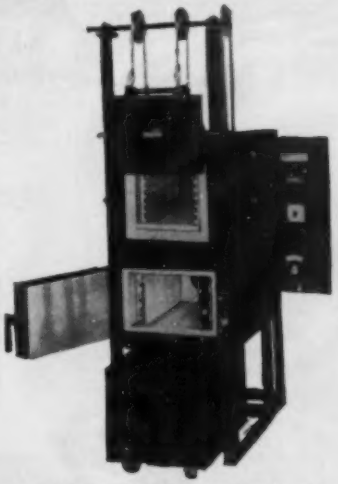

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Two independent furnaces (hardening and drawing) in the same floor space one requires. Complete with independent controls. Hardening furnace available in both a 2000° and a 2300° F. range.

Drawing furnace has a maximum of 800° F.* Quench tank included with the exception of the largest standard model.

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8055 A	6"	x 6"	x 12"	$ 865.00	$ 975.00
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*Also available up to 1250° F.

WRITE FOR FREE LITERATURE, SPECIFICATIONS and price list of Lucifer Furnaces in wide range of sizes—top loading and side loading types. Engineering advice without obligation. Write, wire or phone today.

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LOAD HEAT TREAT FURNACES automatically

Meters... Conveys... Elevates up to 5,000 lbs. per hour

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MICHIGAN Chain & Conveyor Corporation

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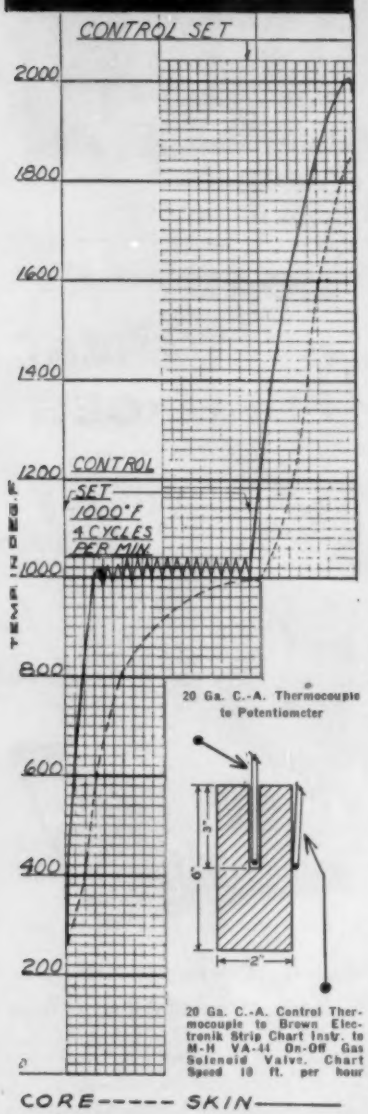
Firing Rate: 50,000 B.T.U. Per Sq. Ft.
Blower Air — 117 C.F.M.



INSPECT THIS PROVEN COMBUSTION SYSTEM

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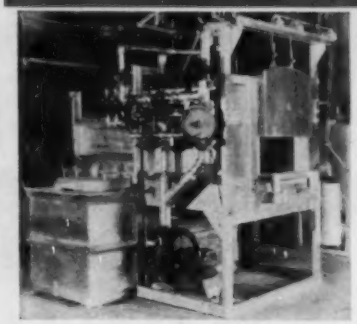
KOZMA *Radiant* ALUMINUM DIE CASTING FURNACES



- Melt and hold in one compact unit
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- Eliminate flame impingement and localized over-heating
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J. A. KOZMA Company

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ELECTRIC FURNACES
custom designed or standard models at practical prices

Dyna-Bar High Temperature Furnace

Dyna-Trol Furnace

- Temperature Range—Dynatrol to 2300° F. Dynabar to 2850° F.
- Dynatrol models—from $90.
- Zone temperature control.
- Pyrometer selector switch for zone temperature indication.
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- Doors—hinged or vertical sliding.
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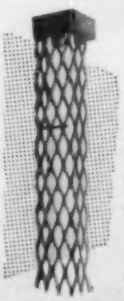
there's a *Glo*-QUARTZ* IMMERSION HEATER for Your Every Heating Requirement



- INSTANT HEATING
- SHOCK-PROOF
- AVAILABLE IN ALL VOLTAGES —WATTAGES, ONE AND THREE PHASE

Available from your Electroplating Distributor

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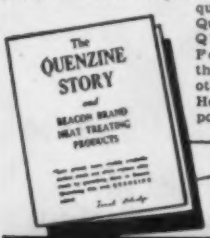

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1000 lb. per hr. S.F.E. recirculating draw furnace, complete with cool down. For temperatures from 250 to 1250° F.

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REWARD

WE PAY CASH FOR SURPLUS INDUSTRIAL FURNACES AND RELATED APPARATUS

SURPLUS FURNACES FOR SALE

BOX TYPE

27x54x20	G.E.	50KW	2000°F
36x72x23	G.E.	72KW	2000°F
48x84x24	American	100KW	1850°F
30x36x18	Surface	Gas	1850°F
54x96x24	Surface	Gas	1850°F

PIT TYPE

25x36	Lindberg	66KW	1250°F
22x26	Lindberg	Gas	1250°F
48x72	Lindberg	Gas	1250°F
48x96	Surface	Gas	1250°F
48x96	Lee Wilson	Rad. Tube	

CONVEYOR TYPE RECIRCULATING

36x33'x12	Despatch	MshBlt	Gas	875°F
27x15'x12	R&S	MshBlt	Gas	1250°F
48x20'x12	Surface	PitBlt	Gas	1000°F

BOX TYPE RECIRCULATING

36x36x36	Despatch	Gas	1250°F
72x12'x42	Lindberg	Gas	1250°F
24x36x18	Lindberg	35KW	1250°F
36x48x24	Lindberg	45KW	1250°F
66x16'x76	Lindberg	180KW	1250°F

PIT TYPE CARBURIZERS

15x18	L&N Homo	30KW	1800°F
20x36	L&N Homo	72KW	1800°F
25x36	L&N Homo	85KW	1800°F
20x48	L&N Homo	85KW	1800°F
24x48	Hevi Duty	100KW	1800°F

ROLLER HEARTH

28"	G.E.	17'htg.	70'C.	320KW	2050°F
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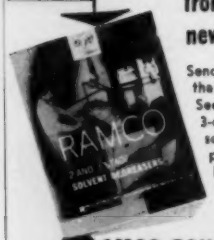

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Castables and Cements

FOR ALL TEMPERATURE AND STRENGTH REQUIREMENTS

Immediate Delivery

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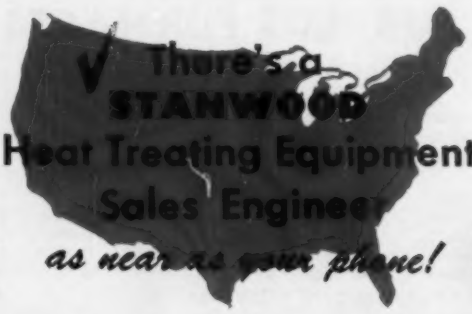

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OIL-KOTE—*solvent type*

SOL-U-KOTE

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Grade "C-W-25"

Non-flammable

Non-toxic

Aqueous Oily Film Protects Ferrous Parts for Long Periods Indoor Storage

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THE LARGEST ENTERPRISE OF ITS KIND IN THE WORLD

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NEW pocket size thickness gauge

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Measures Non-Magnetic Coatings with ± 5% ± .0001" Accuracy

ELCOMETER measures thickness of porcelain enamel, paints, platings, foils, glass, paper, plastics, and other non-magnetic coatings quickly and accurately. Gauges flat or curved surfaces and hard-to-get-at spots easily. Needle locking device assures correct reading every time. Complete with tough leather case containing inner pocket for test strips. Weighs only 6 oz. Completely self-contained. Retail price: $68.00 F. O. B. Cleveland.

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Electrochemical etcher for faster, better, lower cost permanent metal markings!

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DUCTILE CHROMIUM

This new ASM book contains a general review, a section on the production of chromium metal, discussion of ductile chromium metal, data on effect of gas on chromium metal, and a conclusion on high-chromium alloys.

From papers presented at the 1955 Metal Congress by 45 investigators.

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Grade "B"
FERROUS METAL PROCESSING
Eliminates . . .

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Toxicity
Dermatitis
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Write for free sample and brochure
Specify Grade "B"

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Mirror-bright finish in any thickness directly from the bath.
Patented

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Crystal-clear solution that produces mirror-bright deposits.
Patented

BRIGHT RHODIUM
Brilliant, fine-grained, non-tarnishing deposits.

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Restores contaminated cyanide plating baths to full, trouble-free operation.
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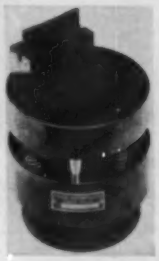

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Complete design facilities for dies or subpress units to press unusual shapes in lab presses.

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Leitz MINILOAD TESTER

FOR VICKERS AND KNOOP HARDNESS

STANDARD HARDNESS TESTERS for ROCKWELL and BRINELL TESTS also available.

Request Catalog 72-1

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SOLVED with

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Electronic Equipment for non-destructive production inspection of steel bars, wire rod, and tubing for mechanical faults, variations in composition and physical properties. Average inspection speed 120 ft. per minute.

Over 80 installations in steel mills and fabricating plants.

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Electronic Equipment for non-destructive production inspection of both non-magnetic stainless and high temperature steel bars and tubing—seamless or welded—as well as non-ferrous bars and tubing. Mechanical faults, variations in composition and physical properties are detected simultaneously. Average inspection speed 200 ft. per minute.

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ULTRASONIC

Thickness Testing from One Side

Rapid, Accurate, Non-Destructive

VIDIGAGE®

14" or 21" Cathode-Ray Screen with direct-reading scales between 0.005" and 2.5"; accuracy 0.1% to 1.0%.

AUDIGAGE®

Portable Thickness Testers for ranges from 0.020" to 4" or 0.060" to 12" of steel; accuracy up to 1.0%.

Detect Laminar Flaws and Lack of Bond

BRANSON INSTRUMENTS, INC.
6 Brown House Rd., Stamford, Connecticut

Specializing in Ultrasonics Since 1946

LIST NO. 81 ON INFO-COUPON PAGE 170

HARDNESS TESTING SHORE SCLEROSCOPE

Pioneer American Standard Since 1907

Available in Model C-2 (illustrated), or Model D dial indicating with equivalent Brinell & Rockwell C Hardness Numbers. May be used freehand or mounted on bench clamp.

OVER 40,000 IN USE

SHORE INSTRUMENT & MFG. CO., INC.
90-35M Van Wyck Exp., Jamaica 35, N.Y.

LIST NO. 133 ON INFO-COUPON PAGE 170

Elevated Temperature Commercial Testing Laboratory for . . .

- **TENSILE**
- **CREEP**
- **STRESS RUPTURE**

Joliet Metallurgical Laboratory, Inc.
31 N. BLUFF ST. JOLIET, ILL.
PHONE JOLIET 2-2328

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the GENUINE BRINELL

HARDNESS TESTING MACHINES made by the Alpha Co. of Sweden and available from our stock at New Rochelle

Never approached in ACCURACY AND CONSTANCY of calibration . . . at the standard 3000kg test load: . . . maximum error plus or minus 2½ kg

Write for Bulletin No. A-18

GRIES INDUSTRIES, INC.
Testing Machines Division
NEW ROCHELLE 3 N Y

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the TRUE TEST is

Taber

TABER
Abrasion
TESTER

Tests wear resistance of metal, plastic, paint, rubber, leather, paper, foil, etc. With average technical experience, anyone can make a scientific, comparative abrasion resistance test with this instrument.

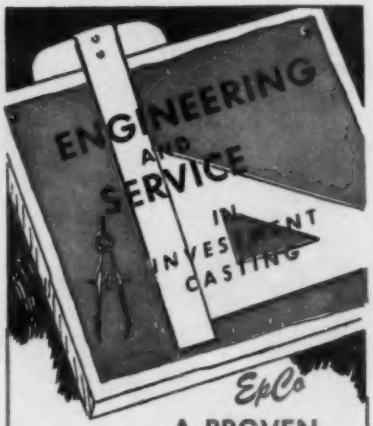
TABER
Stiffness
TESTER

Determines the initial, basic stiffness or resilience of sheet and wire specimens. Eight test ranges provide wide application. Test length, angle of deflection, rate of loading all standardized for accurate results between laboratories. Scale calibrated in gram centimeters.

Write for Illustrated Literature.

TABER INSTRUMENT CORPORATION
SECTION 19
111 Goundry St., N. Tonawanda, N. Y.

LIST NO. 109 ON INFO-COUPON PAGE 170



EpCo

A PROVEN DEPENDABLE SOURCE
FOR BETTER GRADE INVESTMENT CASTINGS IN FERROUS AND NON-FERROUS METALS

INVAR CASTING Special Feature — Nickel content held to 35% minimum — 36% maximum

STAINLESS STEEL PART for milk bottling unit formerly machined from solid stock. Only finish operations required are reaming small dia. of counterbored hole and drilling and tapping for set screw.

ENGINEERED PRECISION CASTING CO.

MORGANVILLE, N. J.

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The *NEW* *Jiffy*

Fastest Cutting Lowest Priced (BROKEN TAP) DISINTEGRATING MACHINE
available anywhere

One of many models. Write for complete information.

See at Booth No. 1575 National Metal Show

JIFFY Disintegrators, Inc.
1583 E. 11 Mile Road, Royal Oak, Michigan

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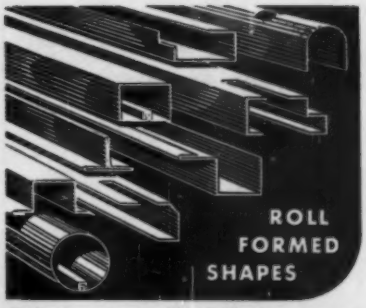

Reduce your assembly problems and costs. Our shapes continuously formed, with high degree of accuracy, from ferrous or non-ferrous metals. Write for Catalog No. 1053.

ROLL FORMED PRODUCTS CO.

MAIN OFFICE AND PLANT
3761 OAKWOOD AVE. • YOUNGSTOWN, OHIO
LIST NO. 101 ON INFO-COUPON PAGE 170

THE NEW
DERMITRON

NON-DESTRUCTIVE COATING THICKNESS TESTER

FAST—ACCURATE
COMPACT—PORTABLE
DIRECT-READING

- *Sorts Metals and Alloys*
- *For Metals on Metals*
- *Non-Conductors on Metals*
- *Metals on Non-Conductors*

You can now have 100% inspection of production of nearly any possible coating on almost any base—including the first and only accurate, direct readings of such combinations as zinc, cadmium, copper on steel; silver on brass; copper on zinc; anodizing on aluminum; organic coatings on non-ferrous metals — without the use of chemicals.

WRITE FOR FULL INFORMATION

UNIT PROCESS ASSEMBLIES, INC. UPA

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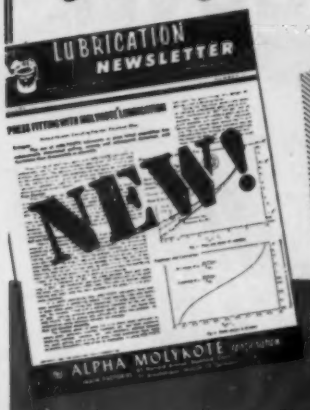
Engineering Data on MOLYKOTE® lubricants



- Being published regularly
- Every issue features a full-length technical article on the use of MOLYKOTE Lubricants in industry.
- "How-to" stories on tough lubrication applications
- Get on our mailing list TODAY. Write to

The ALPHA MOLYKOTE CORPORATION
Main Factories:
65 Harvard Avenue, Stamford, Conn.
71 Arnulfstrasse, Munich 19, Germany

LIST NO. 110 ON INFO-COUPON PAGE 170

make hardness tests
ANYWHERE
WITH THE
NEWAGE
TESTER

- CLAMPS, JAWS & BASE PLATE ARE ELIMINATED
- NO CONVERSIONS OR CALCULATIONS
- TEST ANY SIZE, SHAPE OR TYPE METAL
- NO SKILL REQUIRED
- SCALE READINGS IN ROCKWELL & BRINELL
- ACCURACY GUARANTEED

Many thousands used by industry and government. Write, wire or call for additional details and prices.

NEWAGE INDUSTRIES, INC.
222 York Road, Jenkintown, Pennsylvania
TUrner 4-8494 Dept. MP

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ROUND, SQUARE, FLAT AND HALF-ROUND WIRE FOR MASS PRODUCTION OF SMALL PARTS

Beryllium Copper • Bronzes
Other Non-ferrous Alloys
Rounded or square edges.
Available with hot-tinned finish for solderability.
Write for descriptive folder.

LFA LITTLE FALLS ALLOYS
INCORPORATED
193 Caldwell Ave., Paterson 1, N. J.

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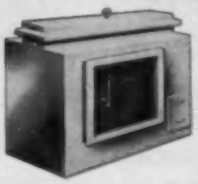
ARco AIR WASH SYSTEMS

PLATING • PICKLING • METAL CLEANING *FUME SCRUBBING*



- Reasonable initial cost . . . economical in operation . . . no moving parts . . . efficient in performance . . . compact—requires little space . . . standard units—7200 to 57600 C.F.M. Write Dept. "MP" for complete information.

AUTOMOTIVE RUBBER CO. • INC.
12550 BEECH ROAD • DETROIT 39, MICH.

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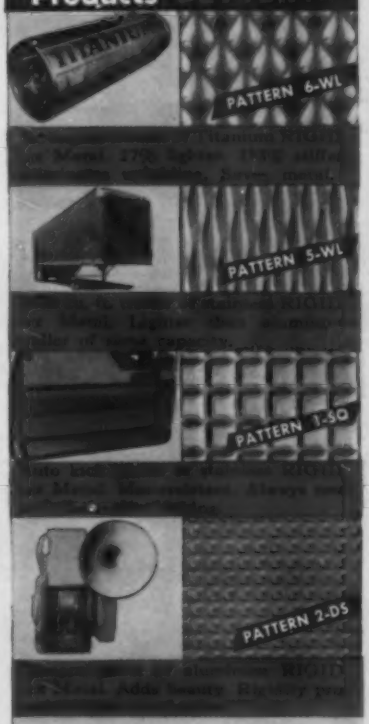
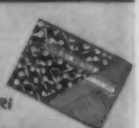
RIGID-tex METAL Makes all these Products BETTER!



RIGID-tex Metal can make your product better too! This new catalog tells how. Copy mailed free.



See Sweet's Design File 1a/Ri or write for information.

RIGID-tex METAL
IT'S RIGIDIZED

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KENTRON MICRO HARDNESS TESTER

Applies 1 to 10,000 gram loads

Write for Bulletin

Kent Cliff Laboratories Div.
The Torsion Balance Company
CLIFTON NEW JERSEY

LIST NO. 53 ON INFO-COUPON PAGE 170

TENSILKUT

Patent Pending

Accurate test specimens machined from sheet and plate materials .0005 to .500 in., in less than 3 min.

SIEBURG INDUSTRIES, INC.
Horse Plain Rd. • New Britain, Conn.

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SPECIAL SERVICE ON *HIGH SPEED* STEEL FORGINGS

FAST NATION-WIDE SERVICE ...YOUR STEEL OR OURS

Complete Source For Forged Products Up To 4000#
Rings, discs, spindles, bars or special shapes to your specifications.

28 Years Of Specialized Experience
In production of high speed tool and alloy steel flat die forgings.

Ample Stocks Of Steel Always On Hand

Expert High Speed Steel Blacksmiths

Call or write for free cost quotation on your forging requirements

Smith-Armstrong FORGE, INC.

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SPECIALISTS IN THE FIELD OF

Die Castings

SINCE 1922

Aluminum and Zinc

THE HOOVER COMPANY
Die Castings Division
North Canton, Ohio
In Canada—Hamilton, Ontario

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WRITE, WIRE or PHONE FOR YOUR CATALOG *Today*

BOLTS & CAP SCREWS
SOCKET, SET & CAP
NUTS, WASHERS
MACHINE SCREWS
SHEET METAL SCREWS
WOOD SCREWS
PIPE FITTINGS

Star Stainless screws have clean—bright—shiny—heads

STAR STAINLESS SCREW CO.

CORROSION RESISTANT

647 Union Blvd., Paterson 2, N. J.
Telephone: Little Falls 4-2300
Direct N.Y. 'phone Wisconsin 7-9041

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DO YOU HAVE AN IDEA...

THAT SOME FUNCTIONAL METAL PART COULD BE MADE BETTER OR CHEAPER BY ALUMINUM EXTRUDING?

Bring your idea to specialists in adapting aluminum extrusions to new functional parts applications. G. E. I.'s engineers are ready to consult with you, without obligation, on one part or a million.

GENERAL EXTRUSIONS, INC.
4040 LAKE PARK RD., YOUNGSTOWN, OHIO

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A CABLE SPLICED IN 10 SECONDS!

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Complete Arc Welding Accessories
2070 E. 61st Place, Cleveland 3, Ohio
Write for Caddy Catalog

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READERS' INFO-COUPON SERVICE, METAL PROGRESS
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Please send further information, as checked at the right, on the advertisements in the Bulletin Board with numbers I have listed below—

(Bulletin Board Item Number)	(Please check) Send Catalog or Engineering Data	Send Price Info	Nearest Source of Supply
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WHITELIGHT

MAGNESIUM

your comprehensive independent mill source of magnesium alloy
Tubes • Rods • Shapes • Bars
Hollow Extrusions • Plate • Sheet
• Pipe • Wire • Welded and Riveted structures and assemblies

WHITELIGHT MAGNESIUM

WHITE METAL ROLLING & STAMPING CORP.
82 Moultrie St., Brooklyn 22, N. Y.
Sales Office
443 Fourth Avenue, New York 16, N. Y.

LIST NO. 67 ON INFO-COUPON LEFT

Personals . . .

Willard C. Suttles has joined the Beardsley and Piper Div. of Pettibone Mulliken Corp., Chicago, as sales representative in parts of Michigan, Ohio and Kentucky. Until taking over his new assignment, Mr. Suttles was associated with the Hill and Griffith Co., Birmingham, Ala.

S. A. Duran is on a two-year leave of absence from his duties as associate professor of physical metallurgy at the State College of Washington, Pullman, Wash. He is spending his leave at Stanford University as acting professor of metallurgy, doing some work on internal oxidation and teaching.

Edgar W. Engle has been appointed development engineer by Kennametal, Inc., Latrobe, Pa., as part of the company's current expansion program; he will be concerned with the development of new products. Mr. Engle, who has been associated with the hard carbide industry for 18 years, was formerly technical director for the Vascoloy-Ramet Corp., Waukegan, Ill.

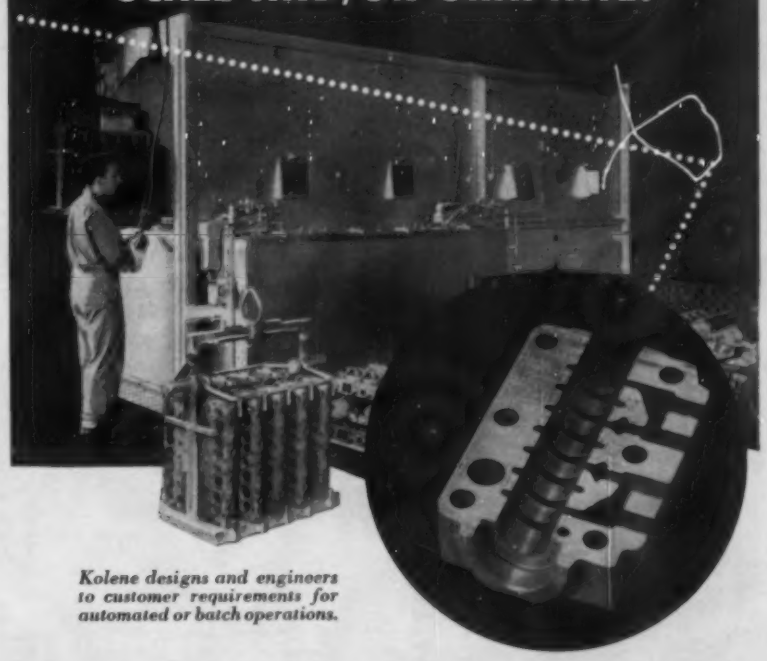
Charles A. Mueller has returned to the Lindberg Engineering Co., Chicago, as chief engineer of the gas process division, a new section which will handle the development of atmosphere gas generation processes for heat treating. For the past few years, Mr. Mueller has been engaged in engineering and metallurgical work in Utah and California.

Albert P. Spooner has retired as chief metallurgical engineer of the Bethlehem Steel Co.'s steel division, Bethlehem, Pa. Mr. Spooner, a past president of the Lehigh Valley Chapter, began his career with Bethlehem Steel in 1915.

William S. Harms, general manager of the St. Louis Steel Warehouse Div. and the Granite City Metal Decorating Div. of Caine Steel Co., Chicago, has been appointed to the board of directors of the company. Mr. Harms began his career with Caine as a salesman in the Milwaukee division in 1948.

James F. Ingram is now serving a three-year tour of duty with the U.S. Air Force and at present is undergoing pilot training.

REMOVES EVERY TRACE OF SAND, SCALE AND/OR GRAPHITE!



Kolene designs and engineers to customer requirements for automated or batch operations.

CASTINGS METALLURGICALLY CLEAN AFTER KOLENE TREATMENT

Intricately cored iron and steel castings of every variety are today being entirely cleaned by the most efficient salt bath cleaning known . . . Kolene's No. 4 electrolytic process. Even the hardest-to-get-at interior surfaces are quickly and thoroughly cleaned of sand, scale and/or graphite in a single operation. Harmful sand particles . . . which frequently become tightly embedded in the casting's surface . . . are removed. Kolening results in a metallurgically clean surface! Casting skin removed—machinability improved!

KOLENE
LEADER IN SALTBATH CLEANING

KOLENE provides complete engineering — equipment — chemicals and service. *No divided responsibility* with Kolene processes.

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in FOREIGN COUNTRIES

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Birmingham 12, England

Heurtey & Cie
Boite Postale 18-16
Paris, France

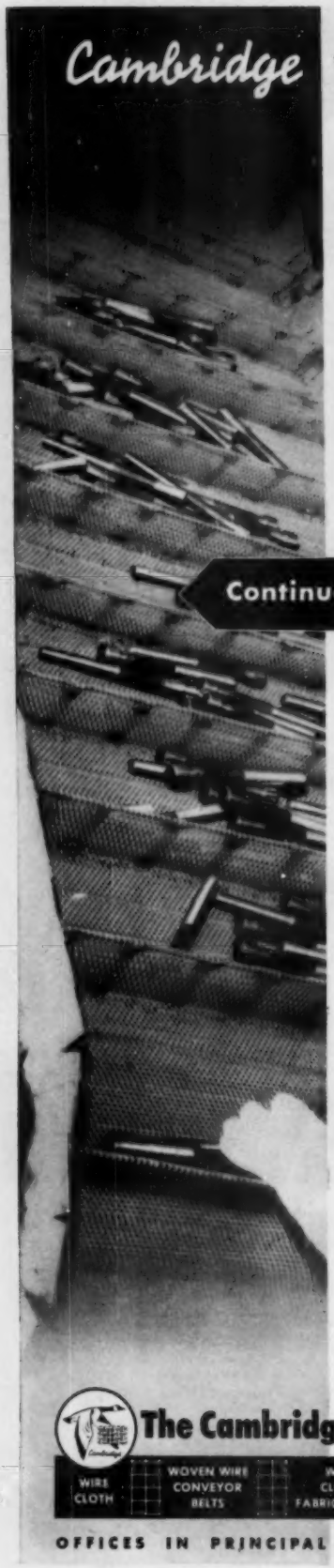
AB Fermeco
Sturegatan 10
Stockholm 5, Sweden

Heurty Italiana
via Leopardi 24
Milano, Italy

DEGUSSA
Dept. Durferrit
9 Weissfrauenstrasse
Frankfurt/Main, Germany

Chemical Plant & Engineering Co. Pty. Ltd.
Ashley Street
West Footscray
Victoria, Australia

CABLE ADDRESS: Koldet



Cambridge

WOVEN WIRE BELTS give you greater production capacity and product uniformity

Belt-to-belt flow of products through annealing, brazing, sintering, tempering, oiling or quenching operations at a controlled rate of speed increases production and assures uniform treatment of parts. By combining movement with processing, woven wire conveyor belts cut costs, eliminate batch handling, simplify operations. EXAMPLE:

Continuous Heat Treating

ALL METAL BELT moves bolts up and through heat treating cycle at a steady, even rate of speed to assure uniformity of treatment. Special alloys withstand temperatures from sub-zero up to 2100° F.; woven wire construction gives longer life because there are no seams, lacers or fasteners to break.

OPEN MESH permits free circulation of atmosphere around all parts of the load to eliminate hot spots and assure uniform treatment. Open mesh also allows quenching or oiling solutions to drain quickly, thoroughly.

SPECIAL CROSS FLIGHTS and raised edges hold product on belt during flat or inclined travel.

OPTIONAL CHAIN DRIVE provides positive motion for heavy loads or inclined movement. Friction drive easily handles most loads.

Cambridge Woven Wire Conveyor Belts are made in any size, mesh or weave, from any metal or alloy, and can be used under a wide range of conditions . . . hot or cold, wet or dry. Call your Cambridge Field Engineer to find out how continuous processing on woven wire conveyor belts can give you greater production capacity and uniformity. Look for his telephone number under "Belting, Mechanical" in the *Yellow Pages*. Or, write for FREE 130-PAGE REFERENCE MANUAL.

The Cambridge Wire Cloth Co.

WIRE CLOTH | WOVEN WIRE CONVEYOR BELTS | WIRE CLOTH FABRICATIONS

Department B, Cambridge 10, Maryland

OFFICES IN PRINCIPAL INDUSTRIAL CITIES

Personals . . .

Reinhard P. Abendroth has been assigned to the minerals and chemicals engineering group of the Metals Research Laboratories, Electro Metallurgical Co., Niagara Falls, N.Y., a division of Union Carbide Corp. Dr. Abendroth's technical background includes positions at the Eberhard Mfg. Co., Sterling Steel Casting Co., and the Los Alamos Scientific Laboratory. Another new member of the Electromet staff is **Edward L. Harmon**, who has been assigned to the metals research group. Dr. Harmon was formerly a research assistant at Case Institute of Technology where he received his undergraduate training and his doctor's degree.

Charles R. Johnson is now a trainee in the metallurgy department of the U.S. Steel Corp.'s Ohio works in the Youngstown, Ohio, district.

William G. Pfann was awarded the Francis J. Clamer Medal of the Franklin Institute "in recognition of his discovery and application of zone refining to metals and other crystalline substances" at the Institute's annual Medal Day ceremonies this month. A graduate of the Cooper Union Schools of Engineering, Mr. Pfann's entire professional career has been spent with the metallurgical research department of the Bell Telephone Laboratories, Murray Hill, N.J.

James J. Barrett has been appointed manager of extrusion sales for the Babcock & Wilcox Co.'s tubular products division, Beaver Falls, Pa. Mr. Barrett, who joined B&W in 1954, will direct the sales of hollow and solid extrusions in this newly created position.

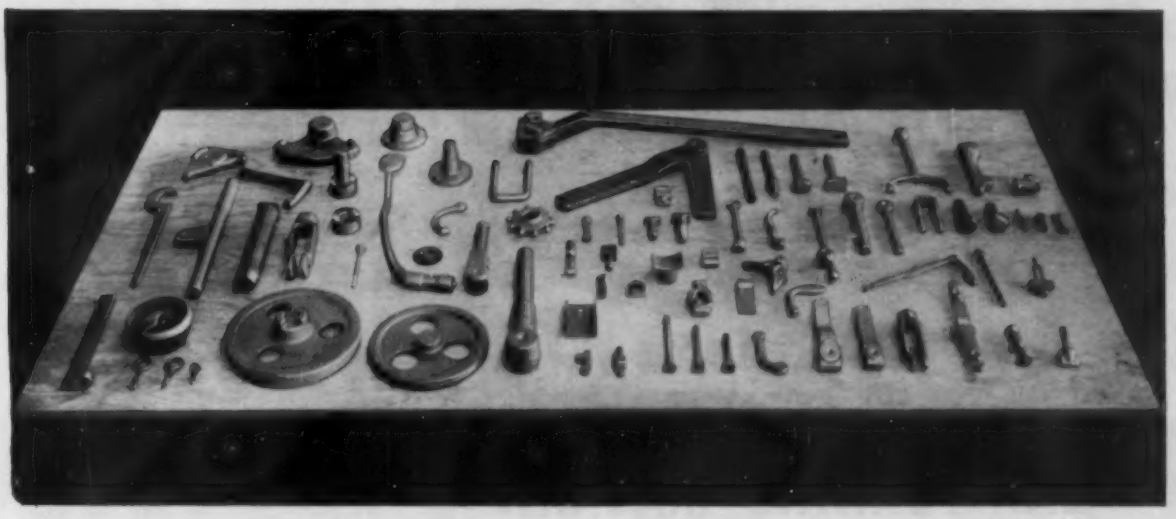
John L. Cook, after release from active duty with the U.S. Army, joined Douglas Aircraft Co., Inc., Santa Monica, Calif. as a materials and process engineer.

Robert W. Lindsay, professor of metallurgy at Pennsylvania State University, has been added to the staff of the central research laboratory of Crucible Steel Co. of America, Pittsburgh. Dr. Lindsay, who has been on the faculty of Penn State since 1943, has assumed the position of supervisor of constructional alloy steels in the laboratory.

200 Different Parts Heated for Forging-

Better, Faster and at Much Lower Cost

with TOCCO* *Induction Heating*



• When progressive production people at General Railway Signal Company installed a 200 kw, 3000 cycle TOCCO machine, they were able to eliminate 7 slot-type oil-fired furnaces and produce better forgings than ever before—at substantially lower costs.

Cost Down—Fuel costs have been reduced from $15.26 to $1.60 per hour with TOCCO. Expensive furnace lining maintenance has been eliminated, and straightening and reheating operations formerly required are no longer necessary.

With oil-fired furnaces all steam hammer operators needed helpers. With TOCCO most of these helper operations have been eliminated.

TOCCO's fast, automatic operation produces almost no scale and achieves uniform temperatures throughout the entire cross section—improving the quality of the forgings and providing increases of up to 40% in the life of the forging dies.

Overall production costs in the forge shop at G.R.S. have been reduced an impressive 35%!

Flexibility—Production runs at G.R.S. range from a low of 15 pieces to a high of over 50,000. Parts from ½ pound to over 25 pounds are heated, merely by changing inductor coils and power control settings.

Better Working Conditions—TOCCO makes the forge shop a better place to work by doing away with noise, dust, dirt, smoke and radiant heat and gases produced by old fashioned furnaces.

If you're looking for a way to produce similar results in your plant, it will pay you to consult a TOCCO Engineer.

TOCCO

THE OHIO CRANKSHAFT COMPANY

Mail Coupon Today—**NEW FREE Bulletin**

The Ohio Crankshaft Co. • Dept: R-10, Cleveland 5, Ohio

Please send copy of "Typical Results of TOCCO Induction Heating for Forming and Forging".

Name_____

Position_____

Company_____

Address_____

City_____ Zone____ State_____

SUTTON presents outstanding
FARMER-NORTON Finishing Machines
Under license from Sir James Farmer Norton & Co., Ltd.

CENTERLESS BAR TURNING MACHINES

Now—U.S. plants can have automatic straight-line bar turning with the finish comparable to the finish of centerless grinding! Machines are fitted with a wide variation of feeds for either rough or precision turning. Ovality tolerances of plus or minus .00025" and a diameter variation better than plus or minus .001" in any 20' length, are achieved for precision turned bars with these machines.

Ask for complete data

Also available:
Silent-Running Swaging Machines
2-Roll Straighteners and Polishers
Strip Flattening & Cutting Machines

SUTTON *Engineering Company*
FIRST NATIONAL BANK BLDG., PITTSBURGH 22, PA.
PHONE: GRANT 1-8077 PLANT: BELLEFONTE, PA.
Manufacturers of Straighteners, Hydraulic Extrusion Presses, Centerless Bar Turners, Rotary Swagers, Sheet Levellers and other Finishing Machines for Modern Metals.

Personals . . .

Stanley C. Watson has retired after 20 years as head of the engineering department of Rayette, Inc., St. Paul, Minn. Mr. Watson will retain his position on the board of directors and will continue to serve the company on a consultant basis.

Francis J. Clauss received his doctorate in metallurgical engineering from the University of Michigan at the June commencement. Dr. Clauss is now continuing his work in the field of high-temperature metallurgy as a member of the nuclear reactor materials section at the Lewis Flight Propulsion Laboratory of the National Advisory Committee for Aeronautics, Cleveland.

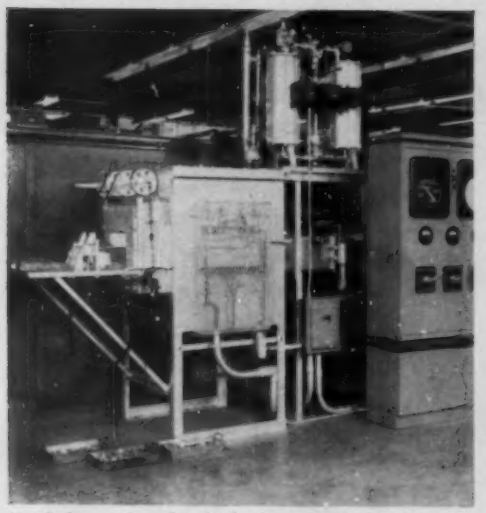
John J. Knox has been named purchasing director of Reading Tube Corp., Reading, Pa. Mr. Knox will also be responsible for the purchasing at Reading Tube's wholly owned subsidiaries, Reading Metals Refining Corp., Readi-Fin Mfg. Co., Inc., and in part for Mackenzie Walton Corp., Pawtucket, R.I. His previous experience in this field includes a position as purchasing director for Hubeny Brothers, Inc., Rosell, N.J.

H. D. Beeson has been promoted to manager, forged disc wheel sales, for the Aluminum Co. of America, Cleveland. Mr. Beeson joined the company 15 years ago, serving first in the smelting plant in Alcoa, Tenn., and later in the Kansas City, Mo., sales office.

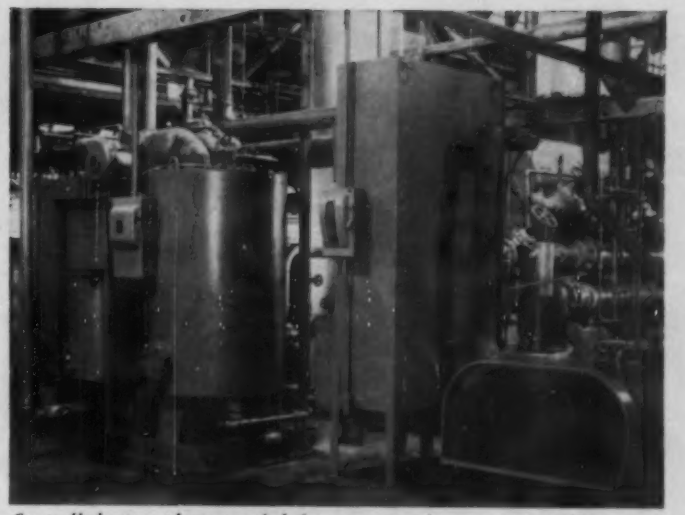
Marvin B. Happ, formerly a research assistant in the department of metallurgy at Massachusetts Institute of Technology, is presently employed as a development engineer with the Walworth Co., Boston.

Robert L. Clark has left the Oliver Corp., South Bend, Ind., to accept the post of chief metallurgist at Century Foundry Co., St. Louis, Mo. Mr. Clark will have responsibility for melting, laboratory control, and supervision of nodular and gray iron castings.

E. L. AuBuchon has left his position as foundry metallurgist with Austenal, Inc., Chicago, to accept a position as works metallurgist, Walworth Co., Kewanee, Ill.

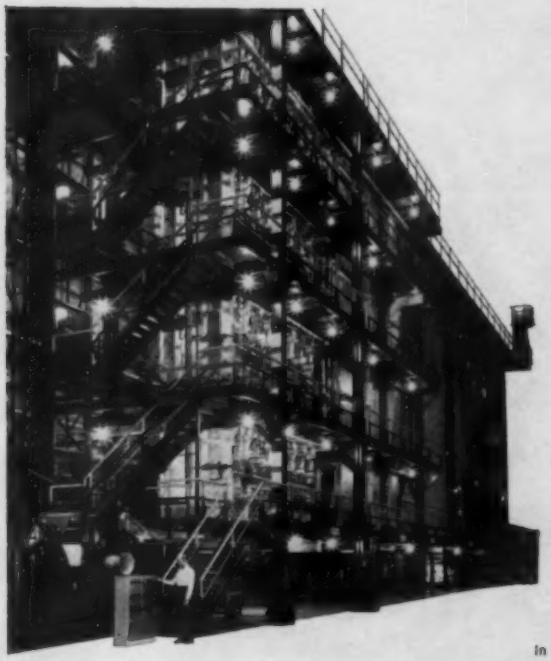


Bottled gas for this little furnace is dried by the Lectrodryer mounted above it.



Controlled atmosphere gas fed from a central generator to all parts of this plant is dried to –40°F. dewpoint by this Type BWC Lectrodryer.

When the controlled atmosphere must be DRY your generator builder will likely recommend a Lectrodryer*



YOUR FURNACE and gas generator manufacturer will advise you on heat treating, brazing and sintering methods and equipment. Where the operation is critical and a DRY atmosphere is indicated, he will likely include a Lectrodryer. It provides dependable DRYing and needs very little attention to keep it working year after year.

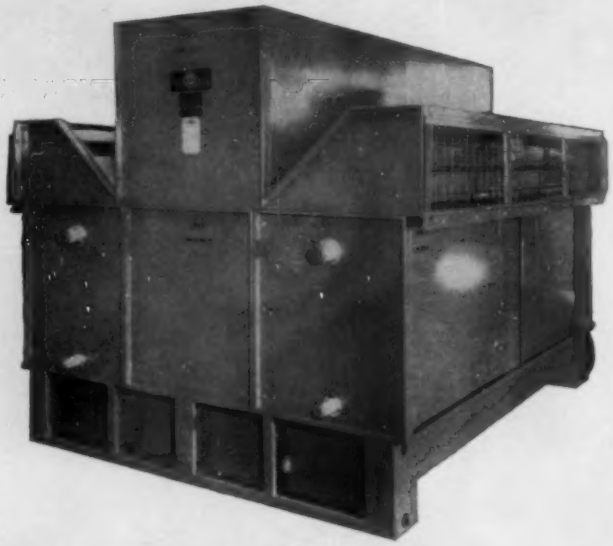
Consult your regular supplier for help on such problems. Pittsburgh Lectrodryer Division, McGraw-Edison Company, 317 32nd Street, Pittsburgh 30, Pennsylvania.

◀ *Five Lectrodryers DRY the 12,000 cubic feet of inert gas that surrounds the 30 tons of tin plate per hour being annealed in this tower-type furnace.*

In France: Stein et Roubaix, 24 Rue Erlanger, Paris XVI.
In Belgium: S.A. Belge Stein et Roubaix, 320 Rue du Moulin, Bressoux-Liege.

Lectrodryer

*REGISTERED TRADEMARK U. S. PAT. OFF.



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***Aero* HEAT EXCHANGER**

gives close temperature control, saves you ***LABOR,*** *Power, Water*

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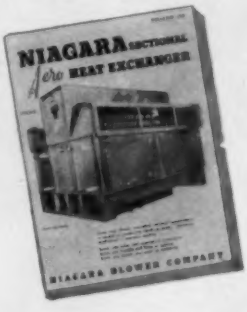

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Personals . . .

Oleg D. Sherby has become a member of the staff of the Office of Naval Research, Dept. of the Navy, London branch. Dr. Sherby's new title is scientific liaison officer in metallurgy.

Basil T. Lanphier has been promoted to a managerial position with the Carpenter Steel Co., Reading, Pa. Formerly a metallurgist for stainless and high temperature alloys, he has been named manager of research. In another promotion by Carpenter, **Howard O. Beaver** has been advanced from plant metallurgist, melting, to production metallurgist in charge of melting and hot working. He joined Carpenter in 1948 and had held his position as plant metallurgist since 1954.

John F. Sargent retired from Wallace Silversmiths, Inc., late last summer after over 35 years with the company. Mr. Sargent started his career with Wallace in 1921, and for 20 years was in charge of the machine department and tool and die heat treating. In 1952 he was appointed factory safety director, in addition to his responsibility for the machine department. A past chairman of the New Haven Chapter, Mr. Sargent is now chapter historian and on the advisory committee.

Charles H. Schwerin has been named manager of West Coast regional sales for the Mackintosh-Hemphill and Rolling Mill Divisions of the E. W. Bliss Co., with headquarters in San Jose, Calif. Mr. Schwerin recently resigned as manager of the industrial furnace division of the Gas Machinery Co., Cleveland.

Several recent graduate metallurgists have been appointed to the staff of the Oak Ridge National Laboratory, Oak Ridge, Tenn., a division of the Union Carbide Nuclear Co. These include **Francis W. Cooke**, **James R. DiStefano** and **William J. Kucera**, all formerly at the University of Notre Dame, and **David T. Bourgette** from Michigan State University.

William B. Smith is now a second lieutenant in the U.S. Army, serving as motor officer in a chemical company in Wiesbaden, Germany.

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Personals . . .

Edward F. Grady is now employed by C. I. Hayes, Inc., of Cranston, R.I., as a sales engineer. Before accepting this post, he was a metallurgist at the Worcester Pressed Steel Co., Worcester, Mass.

Ernest G. Wolff is now serving as a private in the U.S. Army. He was formerly a research engineer at Stora Kopparbergs Bergslags A.B., Domnvarult, Sweden.

Several members in the metallurgy division of the University of Denver's Research Institute have received promotions as a result of the Institute's rapid expansion in the past months. **Joseph F. Nachman** was named manager of alloy development and will be responsible for the administration and supervision of research in this field. Before coming to DRI, Mr. Nachman was chief of the metallurgy branch, magnetics division, Naval Ordnance Laboratory. The new manager for physical metallurgy is **William M. Mueller**. Dr. Mueller formerly headed up the metallurgy group at Dow Chemical Co.'s Rocky Flats plant near Denver and taught in the metallurgy department of Colorado School of Mines. Named as branch chiefs of the DRI metallurgy division were **Charles E. Lundin**, alloy systems; **Dr. Andrew J. Frank**, metal chemistry; **Frank C. Perkins**, plastic flow and fracture; and **Robert A. McCune**, X-ray analysis.

H. Philip Leighly was appointed educational coordinator for the graduate program in physical metallurgy which began this fall at the University of Denver. Dr. Leighly was employed by Bendix Aviation Corp. as materials consultant for nuclear reactor design before coming to the University's Denver Research Institute; he has also taught undergraduate courses at the University.

Peter M. Moanfeldt has joined the staff of the Metals Research Laboratories of the Electro Metallurgical Co., Niagara Falls, N.Y., a division of Union Carbide Corp. A recent recipient of a bachelor's degree in metallurgical engineering from Lehigh University, Mr. Moanfeldt is assigned to the metals research group as technical assistant.

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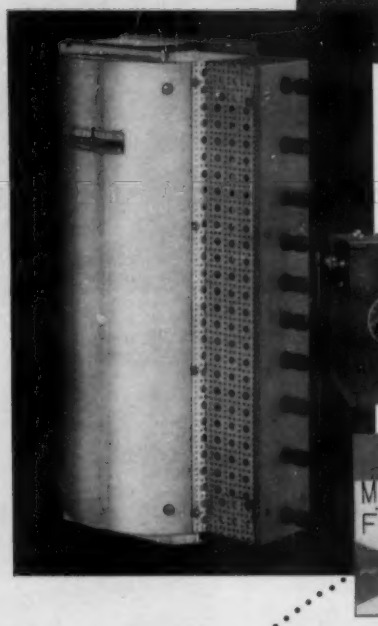

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Personals . . .

Kenneth E. Caine, Jr., has been appointed technological assistant in the bar, plate and forged products division of U.S. Steel Corp. Applied Research Laboratory, Monroeville, Pa. Mr. Caine, a June graduate of Case Institute of Technology, worked at the research center for two summers as a college trainee in U.S. Steel's summer employment program for undergraduates.

Graham E. Wagner has been inducted into the U.S. Army and is currently taking basic training at Fort Carson, Colo.

Byron B. Clow has been appointed assistant product manager, forgings, for Kaiser Aluminum & Chemical Sales, Inc., Chicago. Joining Kaiser in 1948 as a sales trainee, Mr. Clow last held the position of manager of sales planning in the business analysis and market planning department.

S. Irving Clock, formerly a metallurgist for Precision Metalsmiths, Inc., Cleveland, has accepted a job as chief metallurgist for Intricast, Inc., Loudonville, Ohio.

Lyle L. Clark has accepted a position as manager of Muskogee operations with the Fansteel Metallurgical Corp., North Chicago, Ill.; he will be responsible for the management of the company's new tantalum-columbium plant now under construction near Muskogee, Okla. Mr. Clark's technical experience includes 18 years with the Buick Div. of General Motors Corp., Flint, Mich., as assistant superintendent of melting and metallurgy, and more recently, several years as supervisor of foundry research at the Armour Research Foundation of Illinois Institute of Technology.

Joseph K. Strickland has been appointed district customer engineer for the Tatnall Measuring Systems Co., Philadelphia, a subsidiary of the Budd Co. Mr. Strickland will cover the New York, New England and northern New Jersey area with headquarters in Fairfield, Conn.

Floyd W. Bennett is now assistant superintendent of the jet division of Ryan Aeronautical Co., San Diego, Calif.

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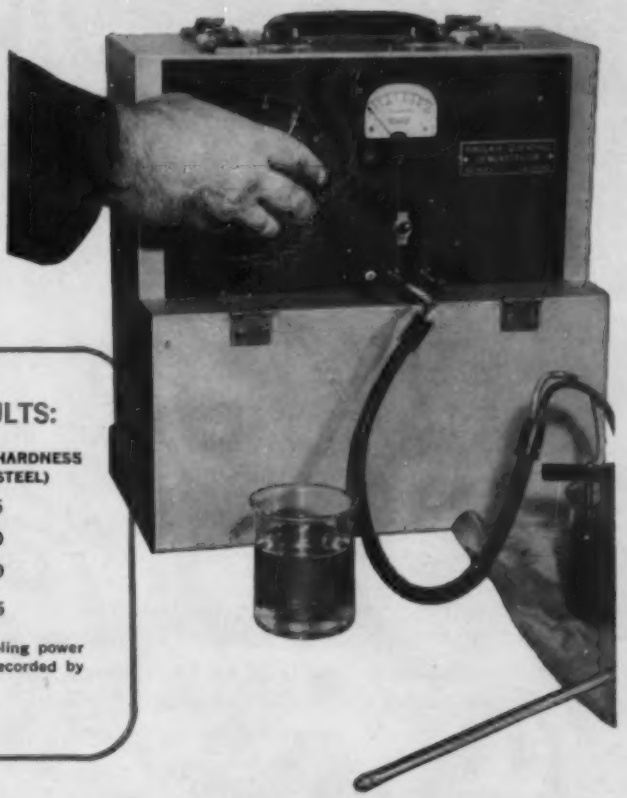

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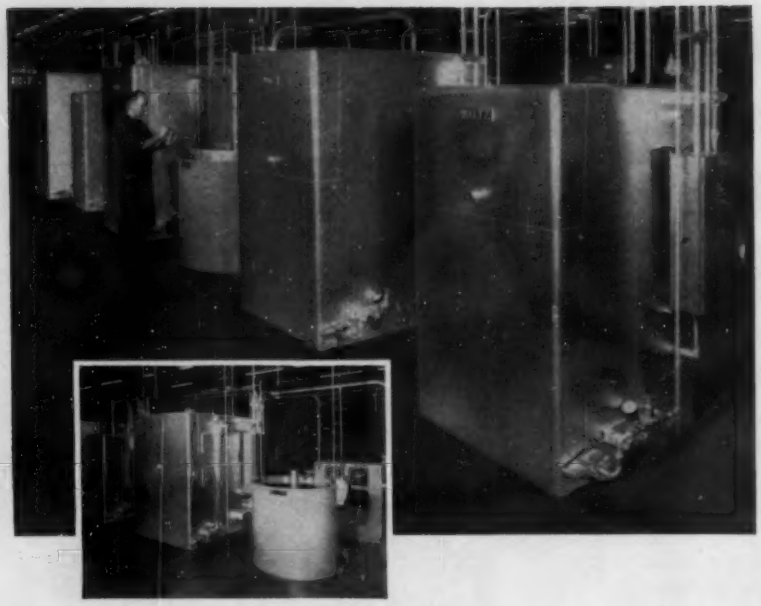

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Personals . . .

Charles W. Haynes has been named associate professor and head of the metallurgical engineering department at Montana School of Mines, Butte, Montana. Immediately prior to coming to Montana School of Mines, Dr. Haynes was senior research engineer for Autonetics Corp., Downey, Calif., and from 1953 to 1956 was a consultant to the Bruning Corp., Lincoln, Neb. Prior to that time he was an associate professor of metallurgy at the University of Nebraska.

George A. Meyer, Sr., is now with Stackpole Carbon Co., St. Marys, Pa., where he will be primarily concerned with research and development work on materials and applications of electrical contacts. He was assistant technical and research director of Malleable Founders Society, Cleveland, before accepting this appointment.

Ted S. Lundy, formerly associated with the University of Tennessee, had joined the staff of the metallurgy division of Oak Ridge National Laboratory, Oak Ridge, Tenn. Other new metallurgists in the division include **Julian H. Cherubini** from Massachusetts Institute of Technology and **Robert W. Swindeman** from the University of Notre Dame.

Richard A. Burkett has assumed new responsibilities as manager of the new Chicago warehouse of Penn Precision Products, Inc., Reading, Pa. Mr. Burkett joined the company in 1954 as district manager in the Chicago-Midwest area, and before that was a sales engineer with the Beryllium Corp., Reading, Pa.

Lenox Rand has been transferred from Pittsburgh to Minneapolis with the U.S. Bureau of Mines.

John H. Hoke has been named supervisor of the stainless steels section of the Central Research Laboratory, Crucible Steel Co. of America, Pittsburgh. Dr. Hoke comes to Crucible from Babcock & Wilcox Co. where for the past three years he has been a research metallurgist at the company's research center in Alliance, Ohio.

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Digests of ASM Convention Papers

Yielding and Fracture of Mild Steel at -320° F.

Digest of "Brittle Fracture of Mild Steel in Tension at −196° C.", by W. S. Owen, B. L. Averbach and M. Cohen, ASM Preprint No. 41, 1957.

THE AUTHORS present a detailed study of the yielding and fracture behavior of long strip specimens of rimmed mild steel (0.22 C, 0.36 Mn) when tested at −196° C. (−320° F.) with deformation rates varying from 8.9×10^{-4} to 1.6×10^{-1} in. per min. When fracture occurred it was always preceded by gross yielding; thus, when the testing speed was increased the fracture stress increased with the yield stress. Microcracks were studied by microscopy at 150 to 1000 × on highly polished surfaces of the flat specimens. Usually, the cracks traversed only one or two ferrite grains although there were instances of several microcracks joined by very severe local deformation. The longest string of cracks was found in specimens subjected to the slowest loading rate and lowest stress. It appears that some single-grain microcracks spread slowly by inducing cleavage in neighboring grains, and at low stresses this process is able to continue for some time before fracture results.

Microcracks and complete fractures are located only in the Lüders bands and usually some distance behind the moving front which delineates the edge of the bands. The complete fractures, described as of the cleavage type, are subject to a time delay which may be separated into three components: (*a*) the delay time for the initiation of Lüders bands, (*b*) the time of formation of microcracks, and (*c*) the interval between their formation and propagation to complete fracture. Evidently the last component is the major time deciding factor.

A few twins were observed in the Lüders' bands but could not be associated with the microcracks. The origin of the microcacks, however, could not be determined. Severe slip at variance with the predominant slip orientation and with exceptionally high steps is suspected.

The authors discuss their results in terms of two theories, one based on the dislocation concept and the other based on a modified Griffith crack concept. Only the latter was found to be applicable to their experimental data.

The effects of a wide variety of heat treatments had been studied previously where it was found that the properties at −196° C. (−320° F.) could be varied from extreme brittleness (950° C. or 1740° F., furnace cooled) to excellent ductility (950° C., air cooled) as shown in the table above.

The authors report that, although microcracks are formed at all loading rates, a minimum stress is required for complete fracture. The minimum stress, as shown in table, is affected by the heat treatment. The magnitude of the Lüders' band strain is similarly affected. It is suggested that fracture occurs when the total crack length—that is, the number of cracked ferrite grains times their diameter—reaches a critical value in the available time and that this critical value is sensitive to heat treatments. F. FORSCHER

Properties of Mild Steel Tested at −196° C. (−320° F.)

	Heat Treatment		
	950° C. Furnace Cool	As Received	950° C. Air Cool
Charpy V-notch transition	+22.4° C.	+15.7° C.	−23.1° C.
Fracture stress * temperature	122,000 psi.	122,000 psi.	186,000 psi.
Reduction in area *	0.3%	2.6%	30.0%
Minimum fracture stress †	<111,000 psi.	116,000 psi.	126,000 psi.

* Round bar. † Flat specimen.

Laves Phases in Transition Elements

Digest of "The Occurrence of Laves - Type Phases Among Transition Elements," by R. P. Elliott and W. Rostoker, ASM Preprint No. 22, 1957.

LAVES PHASES are compounds having the general formula AB_2 and structures of the type possessed by $MgCu_2$ (cubic C_{15}), $MgZn_2$ (hexagonal C_{14}), or $MgNi_2$ (hexagonal C_{36}). These compounds have similar structures, consisting of double layers of hexagonal arrays of magnesium atoms surrounded by tetrahedra of the B elements. In $MgCu_2$, the structure consists of layers stacked ABCABC while $MgZn_2$ consists of layers stacked ABABAB, and $MgNi_2$ is a transition between the two structures with stacking of the layers ABACABAC.

Most of the transition metals of the fourth, fifth, and sixth periods form laves phases of either the $MgCu_2$ or $MgZn_2$ type. Closest packing would exist when the ratio of the atomic diameters of A and B equals $\sqrt{3/2}$ or 1.225. There was no trend for either the $MgCu_2$ or $MgZn_2$ type phases formed by the transition elements to possess or depart from the 1.225 ratio. However, it was noted that when the B elements were arranged in order of increasing atomic number—that is, vanadium, chromium, manganese,

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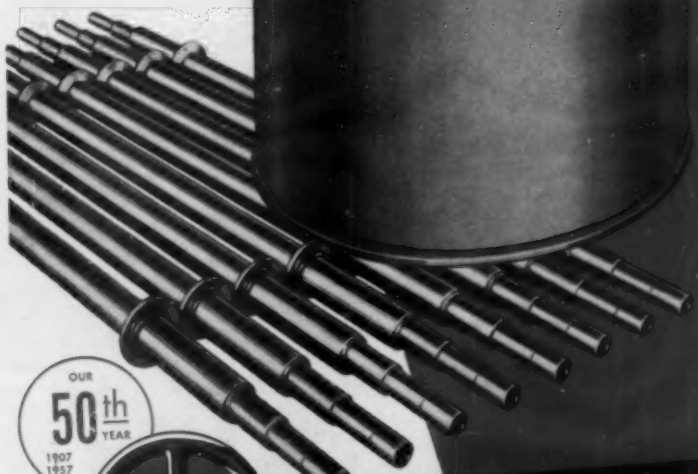

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Laves Phases . . .

iron and cobalt – the laves compounds formed with vanadium or chromium as B elements in AB_2 generally had the $MgCu_2$ structure, while the laves compounds with manganese and iron as B elements generally had the $MgZn_2$ structure, and with cobalt as the B element the laves compounds had the $MgCu_2$ structure again. The transition from $MgCu_2$ type to $MgZn_2$ type and back to $MgCu_2$ type suggested that valence was important in determining whether the laves compound had the $MgCu_2$ or $MgZn_2$ structure. Either the electron-to-atom ratio in AB_2 increased to a peak and then decreased as the B element in the V, Cr, Mn, Fe, and Co sequence progressed from vanadium to cobalt or the valence (electron-to-atom ratio) continuously increased or decreased. Previous work by Witte indicated that the discontinuity on the density of states curve for the $MgCu_2$ type should be at an electron-to-atom ratio of 1.83 and the discontinuities for the $MgZn_2$ type at ratios of 1.93 and 2.32.

The solution to the problem came from a study of the occurrence of laves phases in ternary systems. It was found that in AB_2 quasibinary systems, such as $Zr(V, Co)_2$ or $Zr(V, Fe)_2$, there are intermediate ranges where the $MgZn_2$ structure is stable, although both terminal phases have $MgCu_2$ structure. This suggests that the valency change is continuous. If it were not, the $MgCu_2$ structure would be stable throughout the system. Thus, it appeared that it was possible to have a group of laves phases, with the $MgCu_2$ type structure stable to an electron-to-atom ratio 1.83; $MgZn_2$ type structure stable from 1.83 to 2.32; and the $MgCu_2$ type structure stable again at electron-to-atom ratios greater than 2.32. Thus it was possible to establish a self-consistent series of valences for the elements as follows: Ti 3.92, Zr 3.25, V 2.19, Cr 1.69, Mn 1.35, Fe 0.92, Co 0.72. Valences for nickel and copper were taken as 0.25 and 0, respectively, to be consistent with the previous valences. Where the laves phase has allotropic forms, for example with $TiCr_2$, it was assumed that the electron-to-atom ratio was 2.32.

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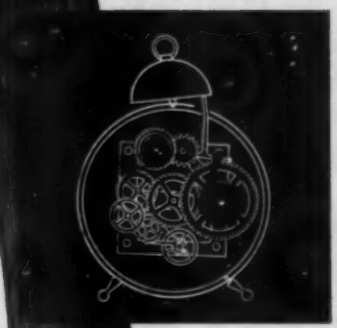

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SS-105

A New Aging Cycle for a Superalloy

Digest of "Effect of Aging Cycle on the Properties of an Iron Base Alloy Hardened With Titanium", by T. W. Eichelberger, ⊕ Preprint No. 21, 1957.

THE AGE HARDENING materials have found extensive use in recent years for engineering applications. Fe-Ni-Cr precipitation hardening alloys developed in the last decade have found wide acceptance for elevated-temperature applications, particularly for jet engine rotors and other parts operating at high stress and high temperature.

Recent investigations aim to improve the mechanical properties through study of the processing variables such as solution treatment time and temperature, and aging time and temperature cycles. This paper describes the development of a new and improved aging cycle.

Age hardening heat treatments for high-temperature applications of these "superalloys" generally follow three general types:

1. Aging at a single temperature for a given time wherein the temperature is usually selected to give substantial hardening in a reasonable period of time.

2. A type of aging denoted "a double age". This treatment is characterized by a high initial aging temperature and a lower final aging temperature. The material may be cooled to room temperature between ages or furnace cooled slowly to the lower temperature. The advantages of the double age are more stable hardness and dimensions, a higher aged hardness for a given hardener content and less effect of hardener content on aged hardness.

3. A type of aging known as "reversed aging". It is derived from the fact that aging is carried out first at a low temperature and then at a higher temperature. Present commercial practice is to air cool to room temperature between ages.

A new type of aging treatment is offered known as "genuage" (general nucleation, accelerated growth) which consists of a reversed age with a controlled rate of heating from the lower to the higher temperature. This aging treatment offers marked improvements in creep and notched-bar rupture properties at elevated temperatures.

Data are presented to show that room-temperature tensile properties and 1200° F. tensile properties are not affected by the type of aging treatment employed. The hardness obtained through aging is apparently the determining factor for all tensile properties.

Creep-rupture properties are greatly influenced by the aging treatment and it is indicated that the long-time (400-hr.), low-temperature (1200° F.) aging treatment produces excellent results but commercially this treatment is not economical. The same properties may be obtained by the new "genuage" treatment which requires much shorter time cycles. This treatment consists of:

1. The aging reaction is started at a low enough temperature to give rapid general nucleation and a minimum of diffusion of the hardener

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Aging Cycles . . .

content to the nuclei in the grain boundary.

2. The aging temperature is then raised slowly, to prevent retrogression, to a higher temperature where the precipitated particles will grow more rapidly.

3. The material is then held at this higher temperature until the desired hardness is obtained.

The temperatures used for the first and second aging steps were 1200 and 1300° F.; however, these are not necessarily the optimum temperatures for every application. Other factors may be involved in obtaining optimum heat treatment for a given part and application.

H. J. ELMENDORF

Transformation Kinetics of Zr-Ti and Zr-Sn Alloys

Digest of "Transformation Kinetics and Mechanical Properties of Zr-Ti and Zr-Sn Alloys", by R. F. Domagala, D. W. Levinson and D. J. McPherson, ⊖ Preprint No. 19, 1957.

IN THIS STUDY of the kinetics of transformation of a number of Zr-Ti and Zr-Sn alloys, the decomposition (beta to alpha) occurred so rapidly that TTT-curves could not be constructed. Effects of isothermal and other treatments on mechanical properties were, however, determined.

Five-pound ingots of the various alloys were first melted in a nonconsumable electrode furnace, then forged into 1-in. diameter rods. These rods were remelted by the consumable-electrode technique and the resultant ingots forged into ⅜-in. diameter, ⅝-in. diameter, and ⅝-in. square stock for the various test specimens. Hafnium-free sponge zirconium was used for all ingots. The alloys tested were zirconium-titanium containing 5%, 15% and 35% Ti, and zirconium-tin containing 4%, 7.5% and 11% Sn.

Attempts to establish TTT-diagrams utilized resistometric methods because a change in resistivity is associated with decomposition of the beta phase.

For short-time isothermal anneals, specimens were "beta-ized" in dy-

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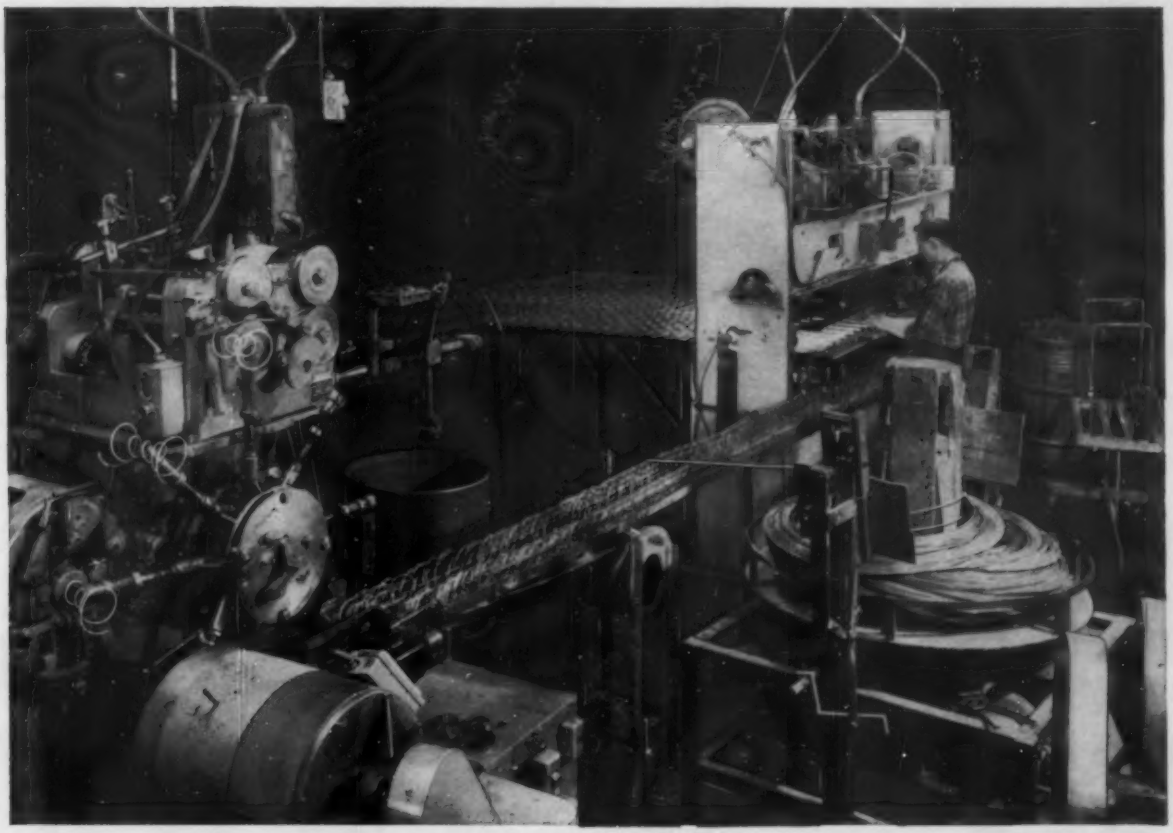

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Zr-Ti and Zr-Sn Alloys . . .

namic helium atmosphere, then isothermally quenched in a deoxidized lead bath or a second furnace. Long-time treatments were performed with the specimens annealed in evacuated Vycor or quartz bulbs. At the conclusion of all anneals specimens were water quenched. Standard ¼-in. tensile specimens and V-notch charpy specimens were employed in determining mechanical and impact properties.

The attempts to establish TTT-diagrams for all of the alloys failed because transformation from beta occurred so rapidly that the equipment used could not detect it. As-quenched resistivity was the same as resistivity of bars isothermally treated and held for periods up to one week. Metallographic examination confirmed this, with structures of titanium alloys originally alpha-prime and only coarsened by isothermal annealing.

Transformation of the tin alloys proceeded in a similar way and though some precipitation to Zr_4Sn was expected, no appreciable amount was observed.

All heat treatments followed the same pattern with mechanical properties (tensile strength, elongation, reduction in area and impact) determined on the following conditions for sponge zirconium and the alloys:

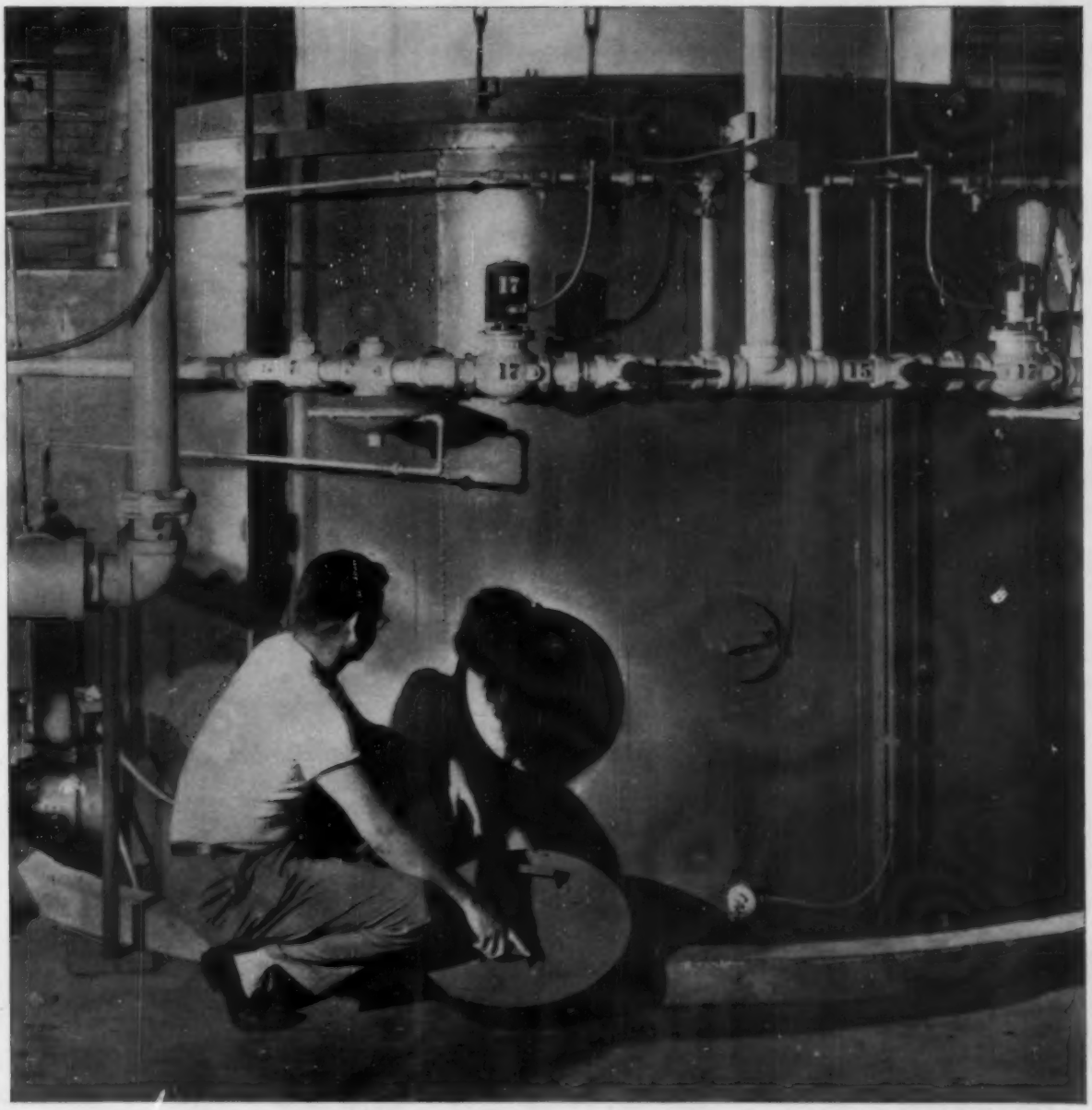
1. Air cooled, furnace cooled and water quenched from the beta field (beta-ized).

2. Beta-ized (heated to beta field), water quenched and reheated to temperatures from 400 to 1100° C. (750 to 2010° F.) for various times from 5 to 1000 min. Temperatures for beta-izing varied from 950 to 1250° C. (1740 to 2280° F.).

3. Beta-ized, quenched to temperatures from 400 to 1100° C. (750 to 2010° F.) and held for various times from 5 to 1000 min.

Results of these treatments can be summarized as follows:

1. Isothermal quench and quench and reheat treatments on all Zr-Ti alloys always resulted in weaker and more ductile properties than the as-quenched properties. On the 15% Ti alloy, beta-ized and quenched to 600° C. (1110° F.) for 180 min. as compared to the water quenched material, the tensile strength dropped from 155,000 psi. to 113,000



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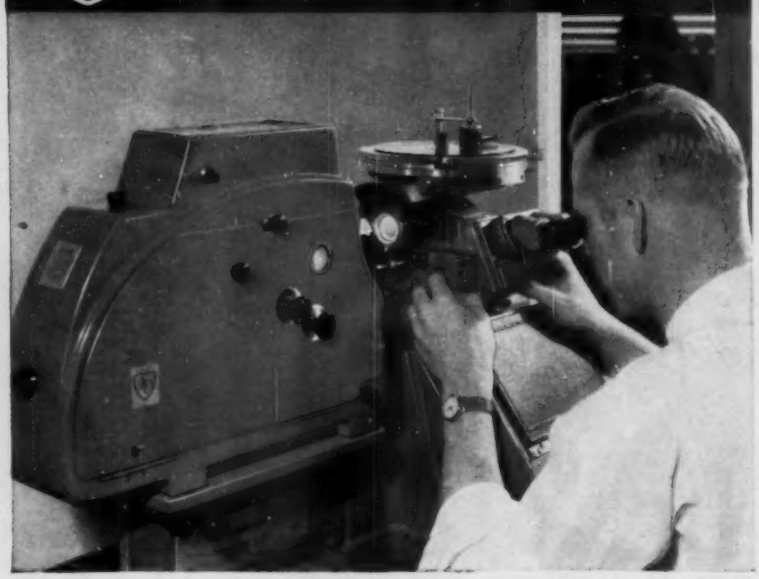

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Zr-Ti and Zr-Sn Alloys...

psi., and reduction of area increased from 2 to 28%.

2. A significant improvement in impact strength was observed on 5 and 15% Ti alloys finish forged in the alpha + beta field.

3. There was a measurable variation in tensile properties with heat treatment of the 4% Sn alloy but no noticeable trend. Highest tensile strength (146,000 psi. with 33% reduction in area) was obtained with beta-ized and water quenched material as compared to 113,500 psi. and 47% reduction in area on material that was beta-ized, water quenched and tempered 30 min. at 950° C. (1740° F.).

4. The 7.5% Sn alloys exhibited the widest range of properties, with tensile strength of 156,000 psi. and 4% reduction in area on material beta-ized and water quenched versus a tensile strength of 123,000 psi. and 38% reduction in area on material beta-ized and isothermally annealed 30 min. at 700° C. (1290° F.). The smallest range of mechanical properties was shown by the 11% Sn composition.

PAUL G. NELSON

Titanium-Columbium Alloys

Digest of "Mechanical Properties and Heat Treatment of Titanium-Niobium Alloys", by L. W. Berger, D. N. Williams and R. I. Jaffee, Preprint No. 15, 1957.

WITH increased quantities of columbium potentially available, its value as an alloying addition to other metals has been investigated. Studies of mechanical properties of alloys with up to 70% columbium are described.

Titanium-columbium binary alloys up to 70% Cb were prepared by inert-gas-shielded electrode arc melting on a copper water-cooled hearth. The melted buttons were fabricated by forging in air at 1800° F. to approximately ¾-in. square cross section and were then rolled at 1300 to 1500° F. to 0.050-in. sheet. Short-time heat treatments above 1300° F. were conducted in protective atmospheres, while other treat-

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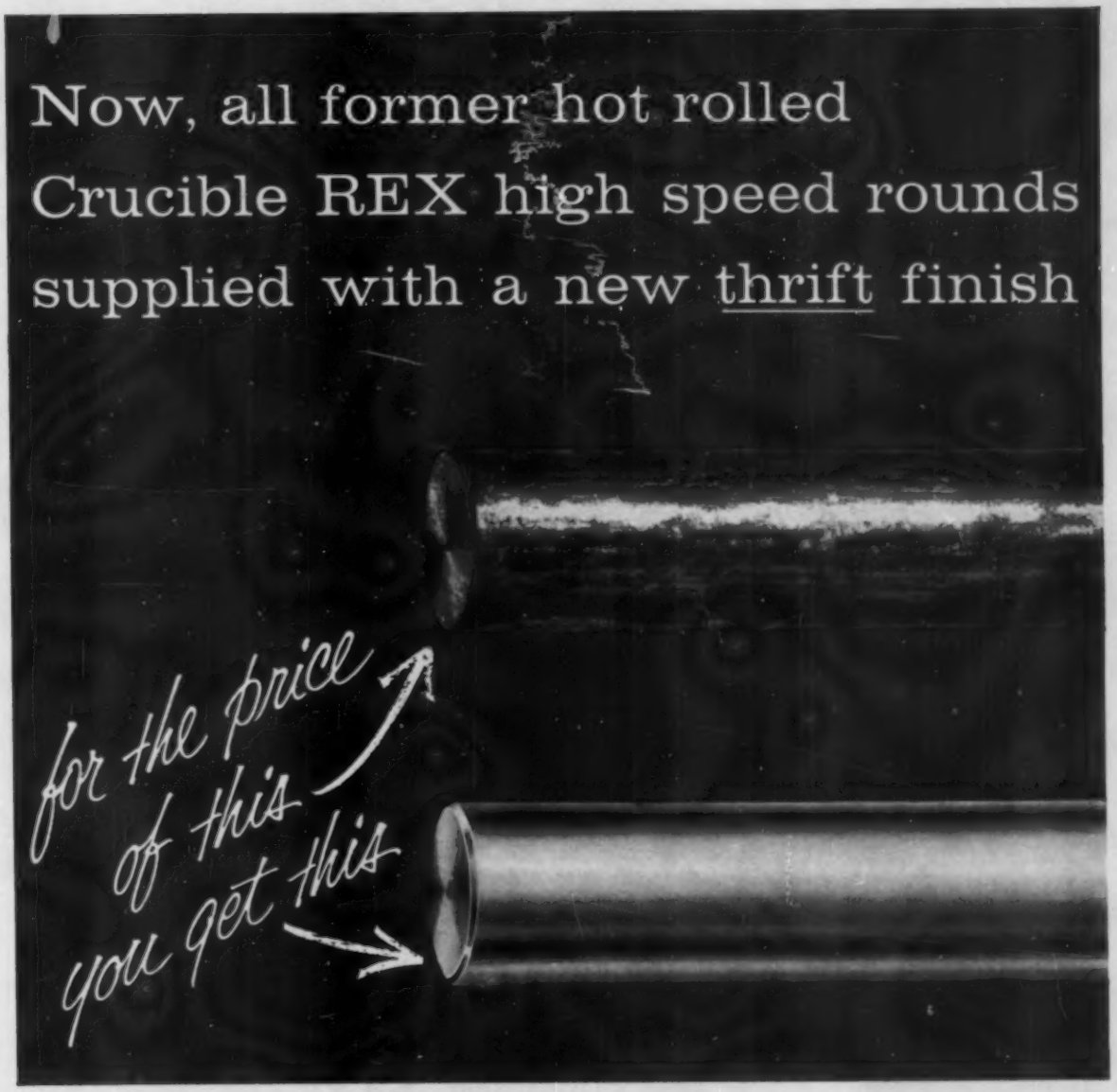

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Ti-Cb Alloys . . .

ments below 1300° F. were conducted in air.

Titanium-columbium alloys are characterized by low strength and excellent bend ductility. Columbium added in small quantities is a very good alpha solid solution strengthener of titanium. Tensile strength properties were significantly increased by additions of up to 3%, with little effect on the elongation values. At slightly higher contents, strength declined but additional amounts above 10% resulted in some alpha-beta strengthening until a maximum tensile strength was reached at 25% columbium. This increase in strength was even more evident in alloys rolled at 1500° F. than the same alloys rolled at 1300° F. A beta quenched 35% Cb titanium alloy had a maximum tensile strength, minimum yield strength, and maximum uniform and total elongation. Metallographic examination revealed a strain-induced acicular phase in the 25 to 40% Cb alloys but not in alloys lower or higher in columbium. The large difference between tensile and yield strengths with attendant increase in uniform elongation was thought to be characteristic of strain-induced martensite transformation such as occurs in other titanium alloys.

The binary alloys of titanium with 50 to 70% Cb are characterized by low strength with a high yield-to-ultimate strength ratio, also with very low uniform elongation, excellent bend ductility and relatively high reduction in area. These beta-phase alloys are mechanically stable with very low work hardening capacity. Necking takes place very shortly on the outset of plastic deformation during tensile test. The stable beta alloys are about equal in strength to the unalloyed titanium. The terminal alpha solid solution of about 3% Cb is, however, considerably stronger than the soft beta alloys.

Tests conducted on a 20% Cb alloy by solution heat treating specimens in increments of 25° from 1200 to 1275° F. indicated that the mechanical properties are quite sensitive to small differences in heat treatment and probably to fabrication temperatures in the alpha-beta field. Previously annealed or stabilized samples containing up to 35% Cb were beta-quenched and checked for hardness to study the martensite transformation. No increase in hardness connected with martensite formation was observed. Age hardening was explored as a possibility with alloys containing 15 to 50% Cb quenched from the beta field and subsequently aged at 800, 900, and 1000° F. Response was best at 800° F. for alloys containing 20 to 35% Cb; however, over-aging occurred quickly at 1000° F. The beta phase becomes increasingly more stable with increased columbium content above 35%. A 50% Cb alloy showed no response to aging for times up to 40 hr. at 800° F. At low columbium contents (up to about 15%), there was not sufficient stabilization of the beta phase and no aging occurred. In all tests, strength was considerably increased by selected aging treatments at the expense of ductility. Extreme brittleness in the 30% Cb alloy was thought to be consistent with the formation of an omega phase.

To summarize, the mechanical properties of titanium-columbium alloys may be varied considerably by solution treatment in the alpha-beta field to control the amount and composition of retained beta. Alloys containing 20 to 35% Cb may be appreciably hardened by quenching from the beta field followed by aging treatments.

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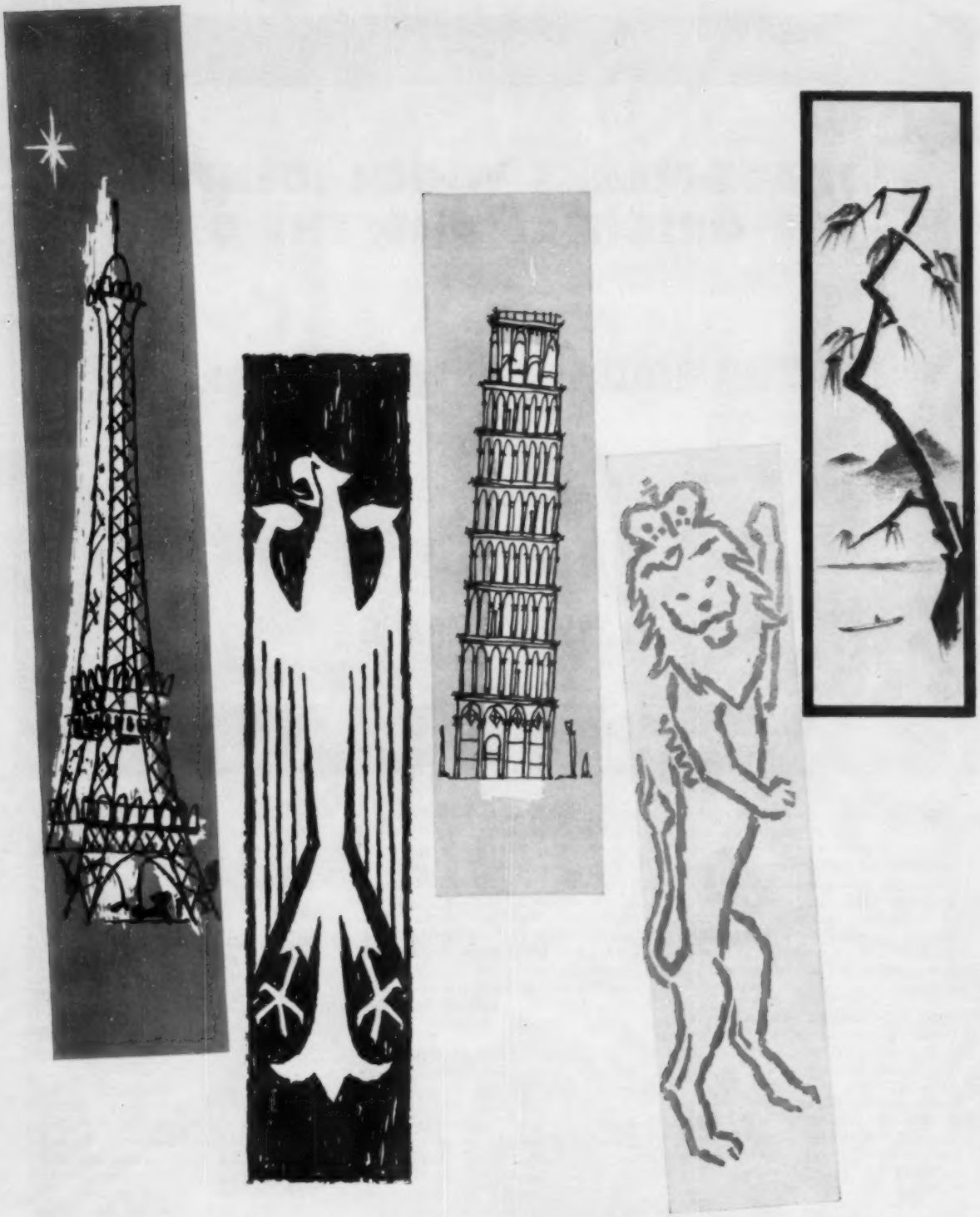

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Electrolytic Extraction of Carbides

Digest of "Electrolytic Extraction of Carbides From Carbon Steel", by R. W. Gurry, J. Christakos and C. D. Stricker, ⊖Preprint No. 4, 1957.

INVESTIGATION of the nature and composition of carbides in steels has been somewhat handicapped in the past by questions raised concerning the extent to which the carbides decompose during and after their extraction from the steel. A comprehensive investigation was carried out to determine the variation in extent of carbide decomposition as related to variations of the individual factors involved in their electrolytic extraction from carbon steel. This work has led to the development of an improved experimental technique for reliable measurement of the amount and composition of carbides electrolytically extracted from carbon steel. Tests show that the proposed new method results in less decomposition of the carbide than other established methods.

Complete details of the experimental work are given in the paper. The apparatus and technique developed are simple but effective. Briefly, an electrolyte consisting of an aqueous solution of cadmium iodide was found to give a minimum of decomposition of the extracted carbide. With this solution, and other conditions optimum, only 6.9% of the fine carbide was decomposed in a "standard" steel sample (0.45% C, 0.80% Mn steel quenched completely martensitic, then tempered 24 hr. at 900° F.). In comparison, the classic method of Klinger and Koch, developed in 1937, using a neutral citrate electrolyte, gave about three and a half times the decomposition of the cadmium iodide solution. A further advantage of the iodide solution is that it was found to be quite insensitive to a large variation in current density. An important feature of the new method is a motor-driven hammering device which sharply and continually jars off the isolated particles from the specimen during the entire extraction period (usually 18 hr.). Without this device carbide decomposition was 2½ to 5 times greater.

After establishing optimum extracting conditions on the standard sample described above, the method was tested on a series of specimens of the same steel, tempered for 24 hr. over a range of 700 to 1300° F. The extent of carbide decomposition varied in a continuous (but not linear) manner, from nil for tempering at 1300° F. to 25.2% for tempering at 700° F. It is explained that with higher tempering temperature the carbide particles are visibly larger and therefore less subject to decomposition. As the tempering temperature is lowered, decomposition increases, particularly below 900° F. The manganese content of the extracted carbides increased with increasing tempering temperature, reaching a maximum at about 1100° F. (24 hr. tempering). This is explained by diffusion of manganese into the carbide during tempering. The authors indicate that this interesting phenomenon is to be the subject of a subsequent paper.

G. H. ENZIAN

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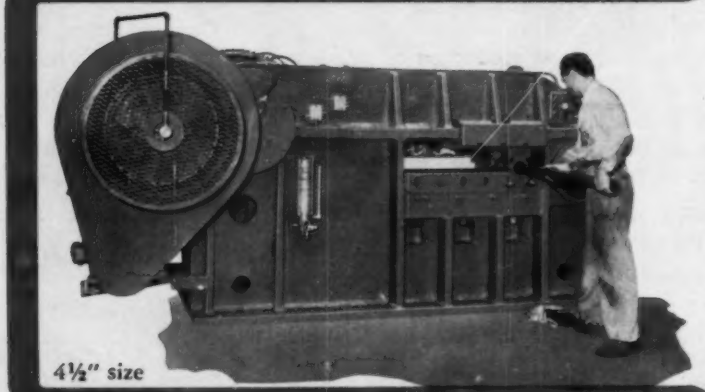

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How a year in the Antarctic proved that USS "T-1" Steel "can really take it"

THE SKIS on these gigantic 10½-ton sleds are made of USS "T-1" Steel. Over a year ago, 38 of the sleds went into service as cargo carriers for the Navy's OPERATION DEEP FREEZE in Antarctica. During that time they have been subjected to temperatures around 69° below zero. Towed by powerful tractors, they have scraped and gouged—400 miles in a single trip—across the rock-hard ice of the South Polar Plateau. And each sled has carried up to 20 tons of cargo per trip.

What has been the effect of this severe service on the skis of USS "T-1" Steel? None. They have remained strong and tough, despite the bitter sub-zero temperatures. No brittleness. No failure. USS "T-1" Steel's hardness has successfully resisted the tremendous abrasive properties of crusted snow and ice. Its toughness has prevented low-temperature impact failure. What's more, its very high yield strength (90,000 psi minimum) permitted the skis to be fabricated from ¼" USS "T-1" Steel plate. Thus, the skis were built *lighter*, yet *stronger*.

The USS "T-1" Steel skis are 154 inches long and 34 inches wide, were cold-formed on a brake press in the shape of troughs. Then the front and back ends of the troughs were notched at the outer line by gas cutting, formed up and together, then welded to make the curved front and back ends of the skis. Welding was done with E-12015 rod.

USS "T-1" Steel is being used to increase strength and durability, while reducing weight and costs in a wide variety of applications from bridge construction to mining equipment. For complete information, write to United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

Sleighs being assembled at landing point in Antarctica. The massive sleighs were designed jointly by the U. S. Navy and Otaco, Limited, of Orillia, Ontario, Canada.

OPERATION DEEP FREEZE

During the present International Geophysical Year (1957-1958), American scientists, with the support of the United States Navy, will, through research at Antarctica, endeavor to advance the world's knowledge of meteorology, glaciology, ionospheric physics, geomagnetism, aurora and air glow, cosmic rays, seismology and gravity.

USS "T-1" CONSTRUCTIONAL ALLOY STEEL

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Pressurizer for designed with stainless

The reactor we are talking about contains a fissionable nuclear core through which passes thousands of gallons of water per minute at elevated temperature and pressure. This pressurized radioactive water transfers heat from the reactor core to a shell-and-tube-type steam generator which in turn produces non-radioactive steam in the secondary system for power turbine operation.

As power requirements change, the temperature of the primary water is maintained by moving neutron-absorbing reactor control rods in or out of the reactor. Resulting pressure and volumetric changes of the primary water system must be controlled, and this is the job of the pressurizer vessel.

When the primary system water pressure drops, high-capacity back-up immersion heaters at the bottom of the pressurizer go into action to heat the water and generate more steam and maintain pressure. When the primary system pressure goes *up*, water sprays inside the pressurizer are activated to collapse the steam bubble, thus reducing the pressure and permitting positive water surges from the primary system. Since the walls are alternately exposed to wetted and vaporous conditions at high temperatures, a severely corrosive environment exists. Corrosion in this vessel could result in a hazardous level of radioactivity throughout the primary side of the plant. The choice of a proper steel to insure against this hazard was a major consideration. This is why the pressurizer was designed with stainless steel.

Electric furnace and metallurgical staffs worked together to obtain the precise chemical composition specified. Great care was taken during processing in the electric furnace shop. Then, forge press crews, heat treaters and machinists combined skills to produce the finished rings, which certainly rank among the finest USS Quality Forgings ever produced.

Your USS Quality Forging order makes use of the same steel-making facilities, the same processing equipment, and most important: your forging is made by the same skilled workmen in our Homestead Forgings Division.

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nuclear reactor system steel USS Quality Forgings

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- Lumnite-made refractory concrete resists extreme variations in temperature and thermal shock due to rapid heating and cooling.
- Durability under severe operating conditions is assured.
- Placement is fast and easy – service strength is reached within 24 hours.

For maximum convenience, use Lumnite-made castables. These are pre-mixed, ready for use, and are made by leading manufacturers of refractories. For more information, write: Universal Atlas, 100 Park Avenue, New York 17, N. Y.

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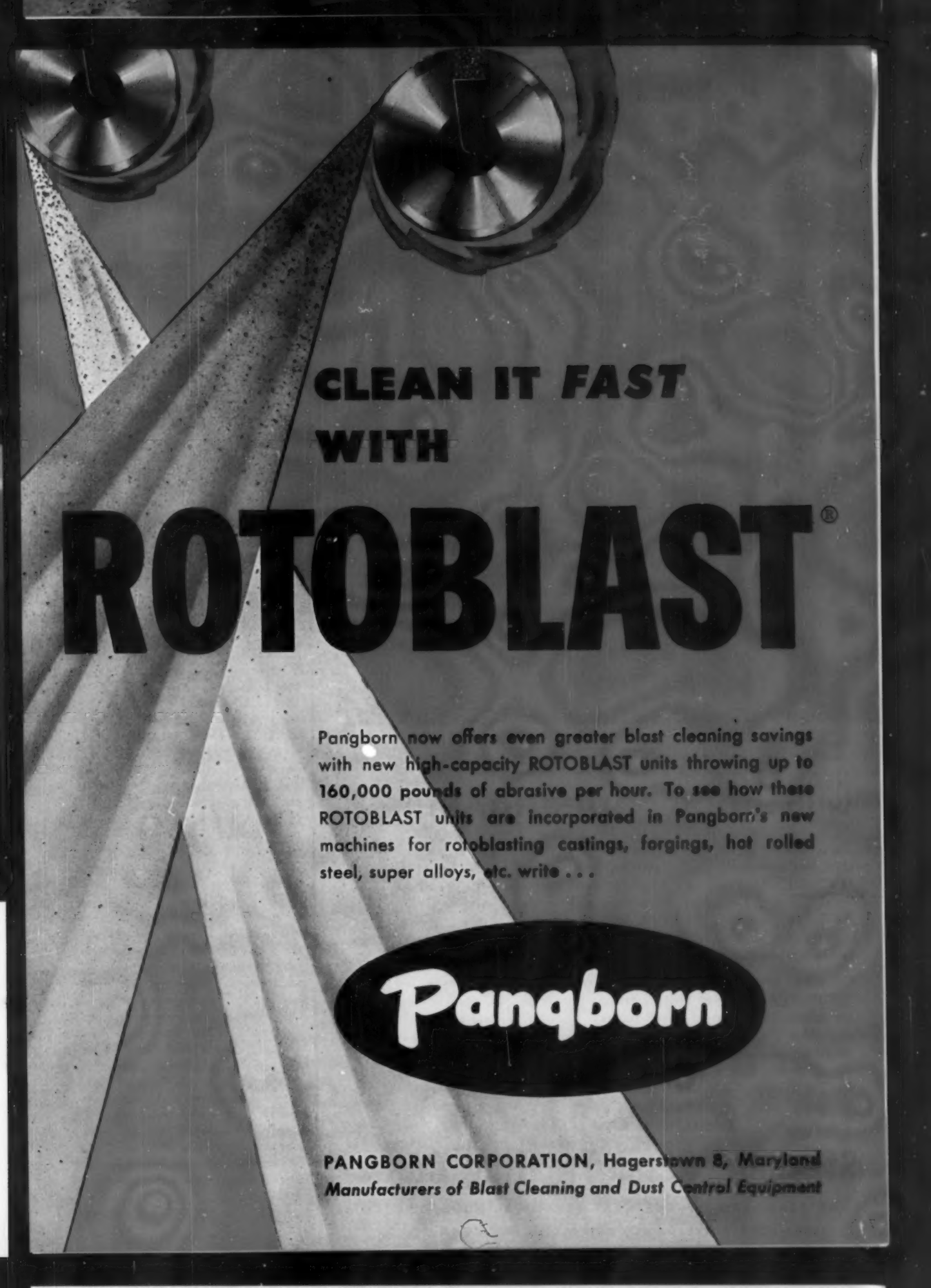
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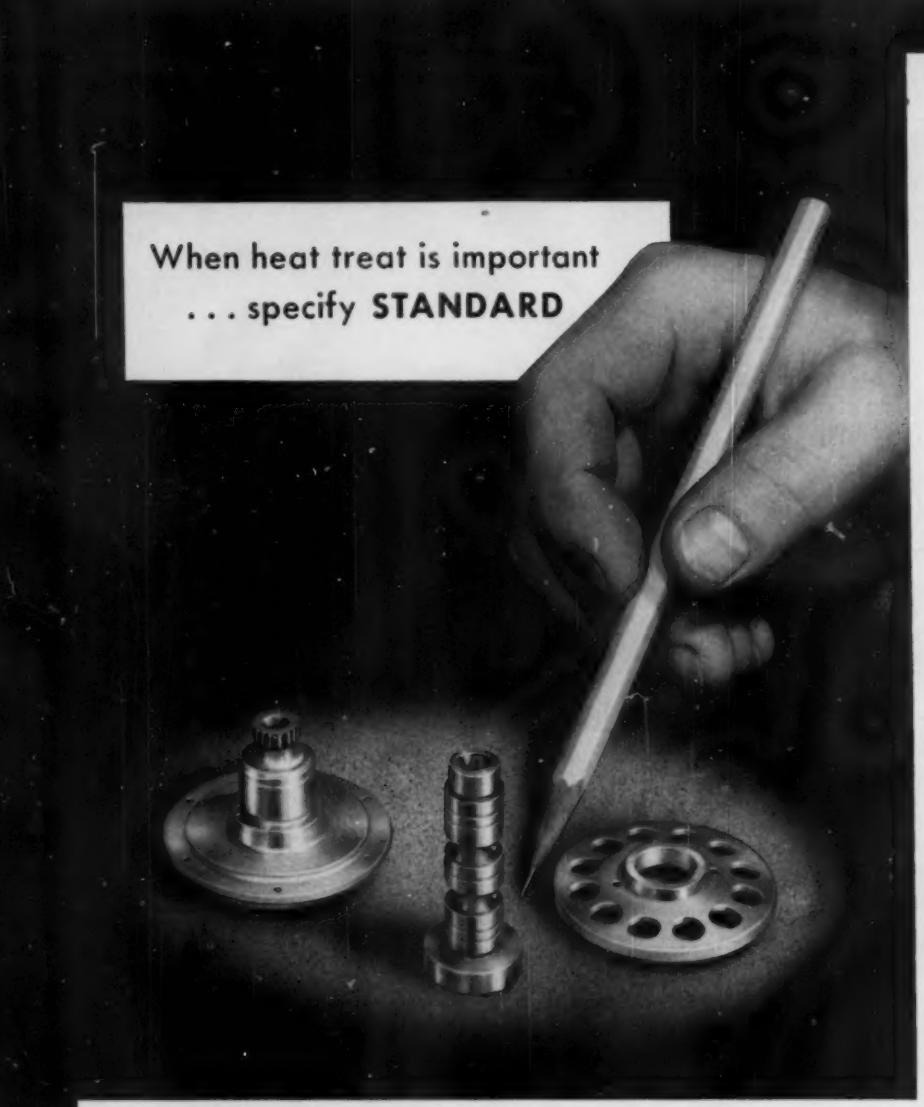

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Grain Size Control of Aluminum 3003 by Preheating

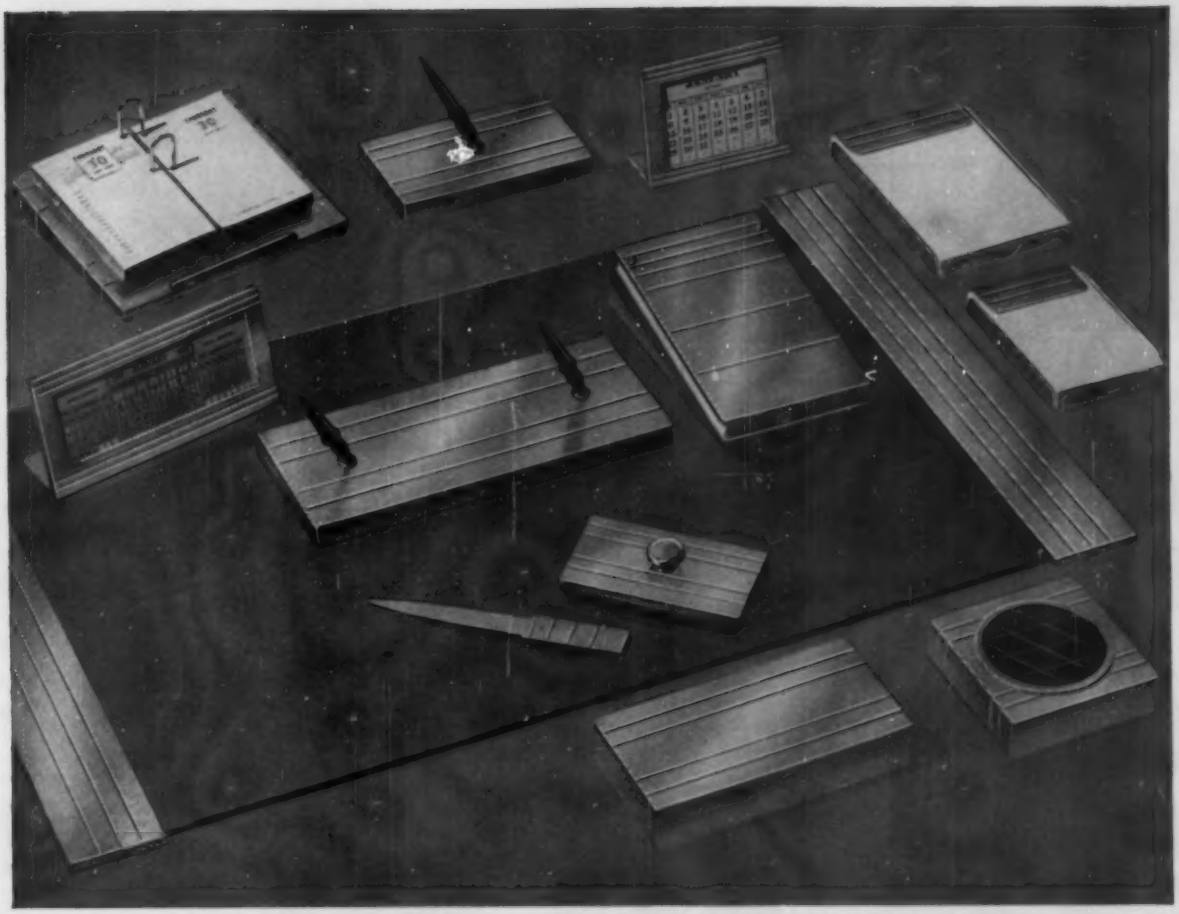
Digest of "The Relation Between Constitution and Ultimate Grain Size in Aluminum-1.25 Per Cent Manganese Alloy 3003", by Philip R. Sperry, ❁ Preprint No. 49, 1957.

HIGH-TEMPERATURE thermal treatments of ingots of aluminum alloy 3003 (1.25% Mn) preparatory to rolling or extrusion have been used for many years as a grain size control measure. If ingots produced by direct-chill methods are given an appropriate high-temperature preheating treatment, it is not difficult to obtain a fine grain in annealed sheet with normal production controls. Omission of the preheating treatment leads to a coarse-grained product. Various mechanisms have been proposed to explain the effects of such thermal treatment, but a more thorough study of the structures and constitution of the alloy as affected by fabricating variables was considered necessary.

In the initial experimental procedure a single large ingot was divided into blocks, one of which was given the high-temperature preheat and the other a lower-temperature treatment. Sheet was rolled from both types. Samples were taken at various stages of processing. The manganese content of the solid solution in these samples was determined by electrical resistivity measurements, while the distribution of silicon between secondary constituents and the solid solution matrix was estimated by microscopic lineal analyses.

These preliminary experiments verified the important changes in recrystallization behavior and ultimate grain size afforded by high-temperature preheating and pointed to accompanying differences in precipitate size and dispersion as the probable cause of the changes. Since differences in the amounts of elements retained in solid solution were also involved, additional experiments were made in which the solid solution concentration and precipitate density were varied independently.

It was concluded that the solid solution composition differences, although they affected the recrystallization range, were not responsible



A few of the fine executive desk appointments made of Formbrite by Smith Metal Arts Co., Inc.

For a superfine luster that lasts—superfine-grain Formbrite

Smith Metal Arts Co. uses easy-to-polish, scratch-resistant Formbrite to add value to its line of distinguished desk appointments.

The fine executive desk appointments made by Smith Metal Arts Co., Inc., Buffalo, N. Y., are not just polished to shine. They are brought up to a beautiful deep luster. For their line of brass accessories they use Formbrite,* Anaconda's superfine-grain drawing brass.

They have found that the fine, uniform grain size of Formbrite enables them to give their pieces a superior, more uniform texture. The luster, furthermore, stands up better under handling because Formbrite provides a harder, more scratch-resistant surface.

In order to achieve this fine luster, Smith Metal Arts Co. must do an exceptional amount of polishing and they have chosen Formbrite because of its superior polishing characteristics. By using Formbrite they can achieve their high quality surfaces at savings of 20% over the use of ordinary brass.

See for yourself. Formbrite is a premium product at a nonpremium price. Find out for yourself how its superfine grain, excellent drawing properties, strength, and scratch resistance can help you improve product quality, lower finishing costs. Write for Publication B-39. Better yet, ask for a sample or details on our trial order offer. Address: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont. BFM

Formbrite

SUPERFINE-GRAIN DRAWING BRASS

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Grain Size Control . . .

for the grain size variations. The tendency for formation of large grains in the low-temperature preheated material existed over a wide range of solid solution composition. At the same time, the high-temperature treatment produced fine grains over a similarly wide range in the composition of the solid solution.

The evidence pointed to the degree of dispersion and size of the precipitate or "dispersoid" particles as the important factor; it also favored an obstruction mechanism to explain the differences in final grain size. The presence of fine precipitate particles in material which was not preheated at high temperature appeared to inhibit recrystallization; however, detailed study of the structures revealed that very fine recrystallized grains formed at normal recrystallization temperatures but growth of these grains was highly selective. The selectivity of growth was attributed to mechanical obstruction by precipitate particles. Since the number of grains in which growth was permissible was limited, the final grain size was large in such material.

The distinguishing feature of the manganese-bearing precipitate present in 3003 alloy, which may explain its strong effects on recrystallization behavior and ultimate grain size, was thought to be its relative stability at temperatures in the hot working and annealing range. This relatively stable precipitate formed because of the tendency for manganese to saturate the solid solution during solidification, and because of its low solid solubility at working and annealing temperatures and low diffusion rate in aluminum.

Additional observations concerned the effects of high-temperature preheating on the mechanical properties. Material not given the high-temperature preheating treatment consistently exhibited slightly higher strength and hardness. This hardening effect appeared to be a further reflection of the greater amount, finer particle size and higher dispersion of the precipitate.

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Measurement of Stored Energy of Ingot Iron

Digest of "The Energy Stored in Ingot Iron Deformed by Torsion at 25° C., −82° C. and −185° C.," by T. P. Wang and Norman Brown, ⊜ Preprint No. 53, 1957.

THE INCREASE in energy of a metal after it has been plastically deformed, known as the stored energy of cold working, has been measured for many metals in the last 20 years. This paper describes an apparatus and presents results for such measurements on Armco ingot iron deformed in torsion at 25, −82 and −185° C. (77, −116, −301° F.).

The apparatus was based on that of Quinney and Taylor (*Proceedings*, Royal Society, London, Vol. 163A, 1937, p. 157), with some modifications. The deformed iron specimen and a similar annealed specimen are heated at the same rate of about 3° C. per min. by identical small electrical resistance heaters placed in axial holes drilled in the iron specimens. A cylindrical radiation shield surrounds the two specimens and is maintained at the same temperature as the annealed iron specimen in order to prevent heat loss to the surroundings. A differential thermocouple determines the temperature difference between the cold worked and annealed specimens. A run consists of heating the

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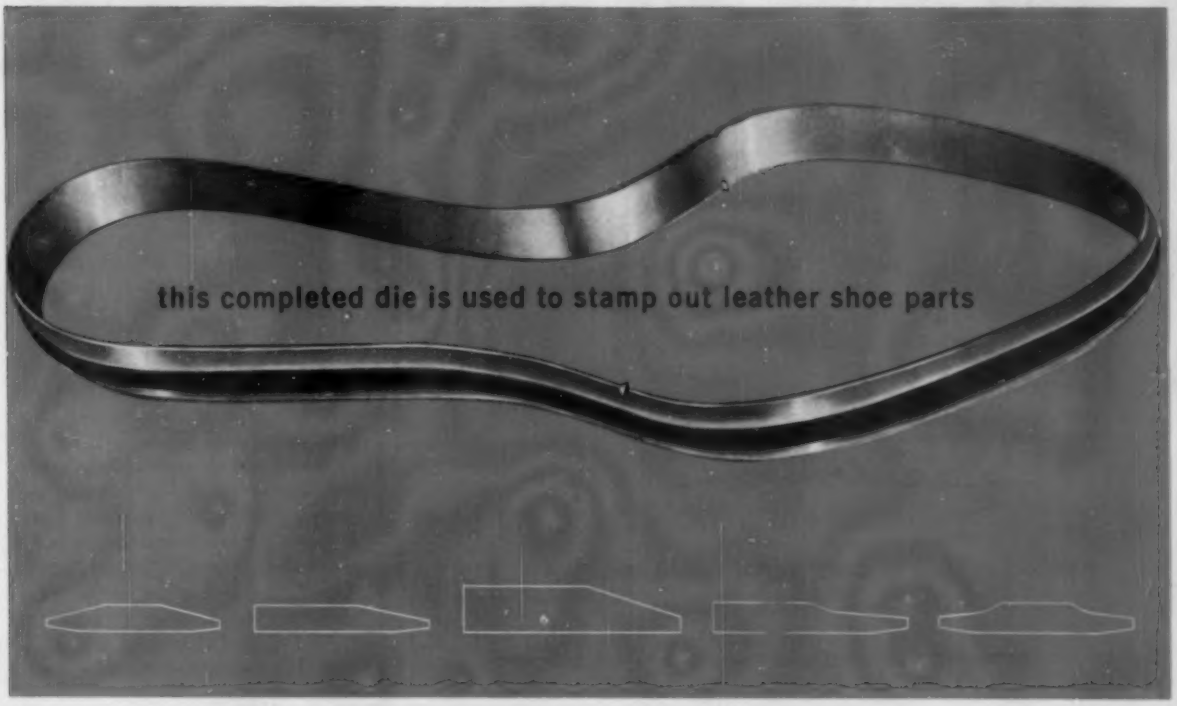

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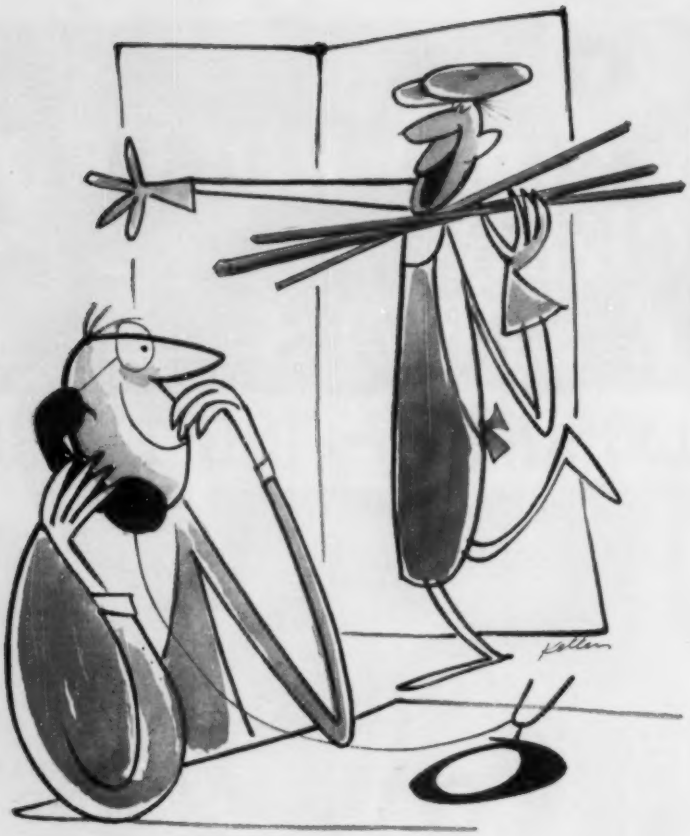

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Stored Energy . . .

specimens to approximately 650° C. (1200° F.) in a vacuum.

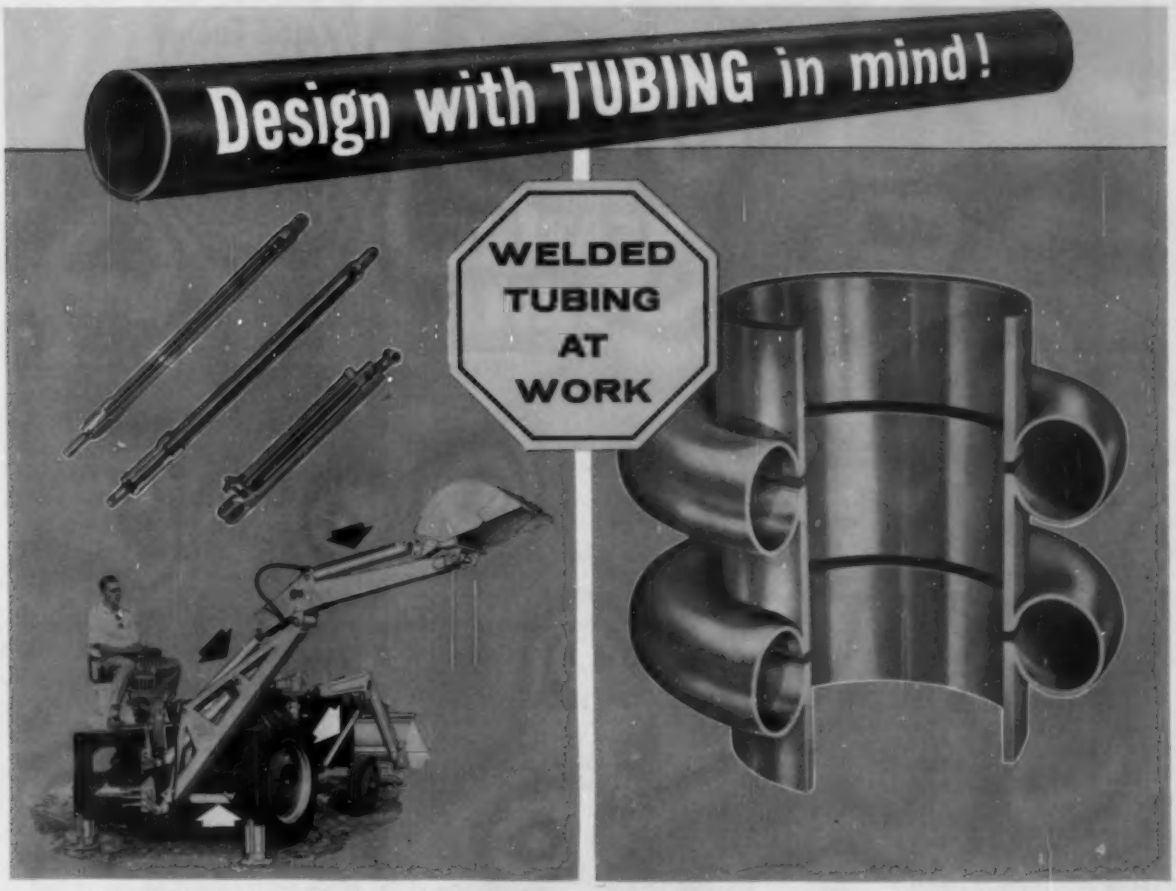
In such an experiment, both specimens have the same temperature during heating (except for small instrumental differences that can be detected by suitable calibration runs) until a temperature is reached at which the cold worked specimen begins to evolve heat as a result of some annealing process occurring spontaneously. The temperature of the cold worked specimen then rises 1 to 5° C. above that of the already annealed specimen, the temperature rise depending on the amount of stored energy released. The results are presented as a curve of the measured temperature difference between the cold worked and annealed specimens versus the temperature of the annealed specimen.

The deformed specimens are prepared from torsion specimens 0.800 in. in diameter with 4-in. gage sections. The deformation is by torsion, ranging from 1½ to 4½ revolutions in the gage length. The mechanical work expended in twisting is then measured and a piece of each torsion specimen saved for microstructural and hardness studies to correlate with the energy release values.

The stored energy is liberated in two stages as the specimens are heated. The first stage takes place at relatively low temperatures ranging from 200 to 500° C. (390 to 930° F.). The second stage takes place at 500 to 600° C. (930 to 1110° F.), and this stage is demonstrated to coincide with conventional recrystallization after cold working. The largest portion of the stored energy is released in this second stage. Typical values reported are 0.15 g-cal. evolved in the first stage and 0.4 to 1 g-cal. in the second stage. These correspond to 1% and 3 to 7% respectively of the work required to deform the specimens. The energy released during recrystallization is greater, the greater the amount of deformation at a given temperature and the lower the deformation temperature for a given deformation.

The first stage of energy release on heating is attributed to recovery processes, possibly including the straightening of bent dislocations, canceling of dislocations of opposite

Design with TUBING in mind!



The hydraulic cylinders operating this Back-hoe fabricate best from Welded Carbon Steel Tubing because of good honing characteristics, uniform roundness and concentricity.

Welded Stainless Steel Tubing formed into this packless expansion joint has served 15 years without failure at temperatures to 1800°F and pressures up to 10,000 psi.

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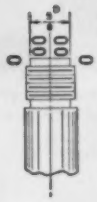
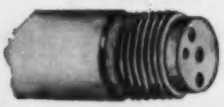
TYPICAL INDUCTION HEATING APPLICATIONS

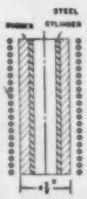
HARDENING
DIESEL FUEL INJECTOR



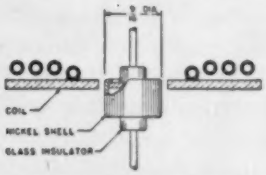
Restriction of heat to end of holder body for fuel injector permits hardening of face to provide required resistance to deformation without hardening the threads. Coil design shown provides uniform temperature for hardening despite holes in face.



REMOVING
RUBBER FROM STEEL



Induction heating develops uniform temperature at steel-rubber interface destroying bond for easy separation. Steel and rubber may similarly be salvaged from mounting brackets, shock absorbers, etc.



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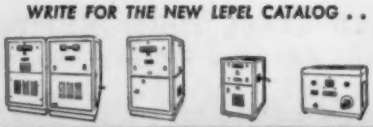

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Stored Energy . . .

sign, and annihilation of vacancies produced by plastic deformation.

Absolute values of stored energy are subject to considerable experimental uncertainty, but the accuracy of the values reported is not mentioned. With the present method, heat interchange must take place between the deformed specimen and the radiation shield, since the shield is maintained at the (lower) temperature of the annealed specimen. The simple method of calculating the heat evolved implies an ideal behavior of the temperature difference curves that is not observed, particularly at the first stage of heat evolution. The calculated values of stored energy released must be regarded as good approximations at best. DAVID A. THOMAS

Transition Temperature for Brittle Fracture of Chromium Alloys

Digest of "Brittle to Ductile Transition Temperatures of Binary Chromium-Base Alloys", by E. P. Abrahamson, II and N. J. Grant, Preprint No. 14, 1957.

CHROMIUM-BASE ALLOYS are attractive high-temperature materials from an oxidation standpoint. However, the lack of room-temperature ductility eliminates much of their usefulness for high-temperature applications. Small amounts of ultrapure chromium have been produced that showed promise of good room-temperature ductility. Addition of several alloying elements has so far only served to raise the transition temperature.

Now the authors have extended the study of the effect of binary addition on the transition temperature of chromium-base alloys to 21 different elements and up to 30% by weight of these elements. They found that all systems showed an initial increase in the transition temperature with the addition of the second element. This increase soon reaches a maximum and further alloy addition causes a decrease in the transition temperature. The decrease may be more or less pronounced but in some compositions,

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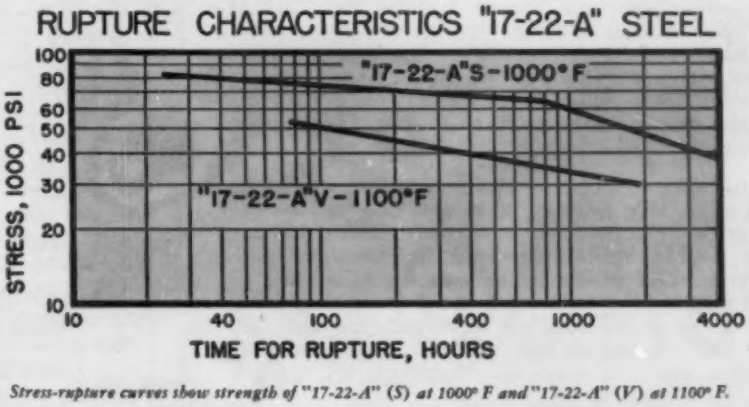
You get more advantages. "17-22-A" steels resist heat checking and thermal cracking. They are readily workable up to 2300° F. They are easily machined and welded. And maximum high temperature properties can be developed by normalizing and tempering, minimizing the possibility of distortion and quench cracking.

Send for complete information on "17-22-A" (S) steel, and its companion analysis, "17-22-A" (V), recommended for temperatures up to 1100° F. Ask for Technical Bulletin 36A. And call upon our technical staff for help with your high temperature steel problems. The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable: "TIMROSCO".



Stress-rupture curves show strength of "17-22-A" (S) at 1000° F and "17-22-A" (V) at 1100° F.

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there's more than meets the eye

In these "LONG JOHN" Muffle Tubes

Even Rolock's welded-fabrication experts consider these 32-foot Inconel muffle tubes an exacting test of skill. The inset sketch shows how they are made, and the dimensions . . . 32 feet long by only 5½ inches O.A. width and 1 inch inside height . . . leave little room for any inaccuracy. These muffles . . . used for continuous bright annealing of steel strip . . . just *have* to be straight and true when installed, and stay that way in service.

We produce these muffle tubes "by the dozen" for use by the steel strip mills in gas-fired furnaces. Upper and lower sections are assembled separately with diagonal joints welded inside and out. The full length sections are then edge-welded together. Tight specifications call for no weld-splatter on the inside, and each tube is pressure-tested to 25 lbs. p.s.i. before shipment. This is another example of Rolock service to key industries in building and designing many forms of special equipment that modern production processes call for.

If you have a problem in welded-fabrication of high heat and corrosion-resistant alloys, it will pay you to consult Rolock . . . the nationally recognized *specialists* in this field.

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Brittleness of Cr . . .

particularly in the Cr-Pd system, the transition temperature is below that of the hydrogen-purified electrolytic chromium used as base metal.

The increase in transition temperature due to impurities in the base metal appears to be additive to the increase due to the second element. Two series of Cr-Pd alloys were tested and curves were plotted of transition temperatures versus atomic percent alloying element. The two curves parallel each other by a distance that equals the transition temperature difference of the two melts of the base metals. It thus appears that alloys ductile at room temperature can be achieved if the transition temperature of the starting materials is sufficiently low. Such alloys may fall into the 60 to 90% Cr range.

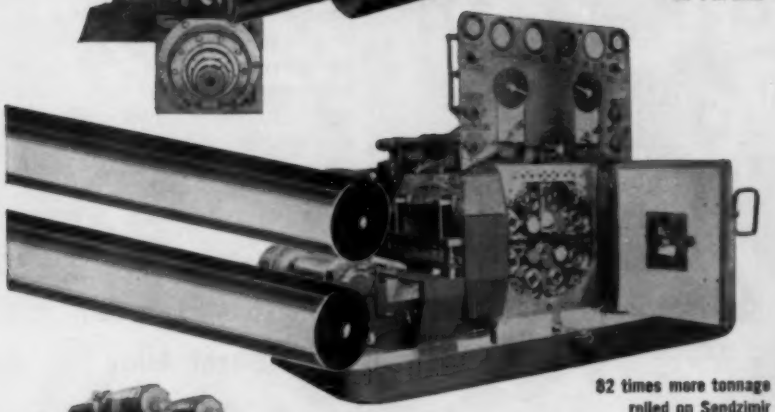
Some series of tests exhibited no maximum in transition temperature and therefore no decrease. This was true in all systems that form a continuous brittle intermetallic phase.

In order to study these inherently brittle materials, specimens had to be used in the as-cast condition, which is the most unfavorable condition for ductility evaluation. All alloys were melted in a purified argon atmosphere in a water-cooled copper crucible using a tungsten electrode. 100-gram buttons were vacuum extracted into a ⅛-in. diameter quartz tube. These rods, with relatively fine and uniform grain size, were then electropolished to remove the thin outer layer of silicon contamination which would otherwise increase the transition temperature several hundred degrees. Specimens were slow bend tested over a 1-in. span in an apparatus capable of reaching 2200° F. The temperature which allows a 65° bend angle was arbitrarily chosen as transition temperature and was plotted against atomic percentage of solute atoms. Some of the binary systems represented by such curves are Cr-Co, Cr-Ni, Cr-Mn, Cr-Fe, Cr-Pt, Cr-Pd, Cr-Re, Cr-Ru, Cr-Rh, Cr-Ir, many of which are carried to nearly 30 at. % of alloying content.

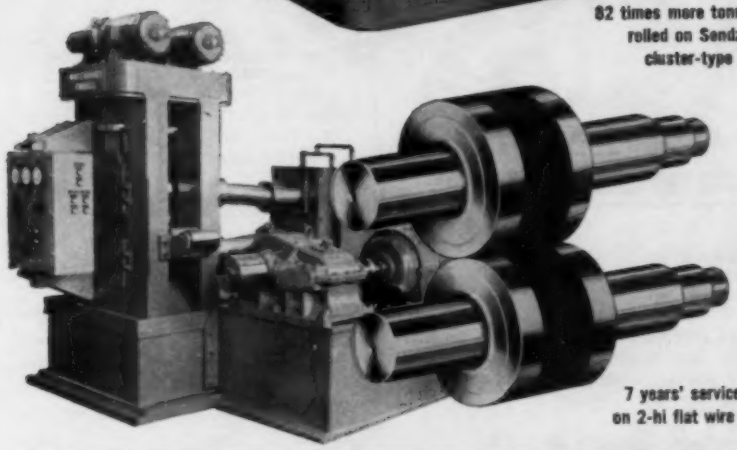
In a search for a general explanation the authors conclude that the configuration of the bonding electron of the solute element is the govern-

Talide ROLLS OUTLAST ALL OTHERS!

1500 coils rolled without a regrind on 4-hi mill.



82 times more tonnage rolled on Sendzimir cluster-type mill.



7 years' service life on 2-hi flat wire mill.

Talide rolls have proven far superior to both steel rolls and carbide rolls of any other make.

During the last five years Talide rolls have been adopted by every major strip steel producer. Metal Carbides pioneered and developed tungsten carbide rolls and successfully adapted them to all types of rolling mills including STECKEL, BLISS, UNITED, MESTA, STANAT, SENDZIMIR, WATERBURY-FARREL, TORRINGTON, RUESCH, FENN, WEAN, COLD METAL, etc.

Talide work rolls are ultra-hard, extremely dense and porous-free. Manufactured from highest purity tungsten carbide powders, the surface finish of a Talide roll is smoother than one micro-inch. Hard as a diamond, it will take a "bigger bite" than a steel roll. Strip steel of all analyses can be rolled down to thinner gauge, with more accuracy, greater reductions and with fewer anneals than possible with any other roll.

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- ★ BETTER FINISH
- ★ LONGER LIFE
- ★ HIGHER SPEEDS
- ★ CLOSER TOLERANCE
- ★ IMPROVED PHYSICALS
- ★ GREATER REDUCTION
- ★ LESS DOWN TIME
- ★ FEWER REJECTS
- ★ LESS MAINTENANCE

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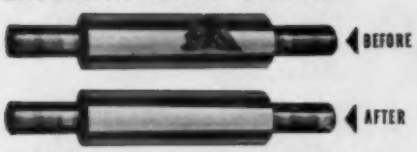

Broken or damaged carbide rolls can be re-worked to first class condition with all defects eliminated at one-half original cost. Only Metal Carbides offers this service—because of its exclusive hot press method.

Talide Rolls are made in lengths up to 100", diameters up to 25", and up to 5000 lbs. by weight.

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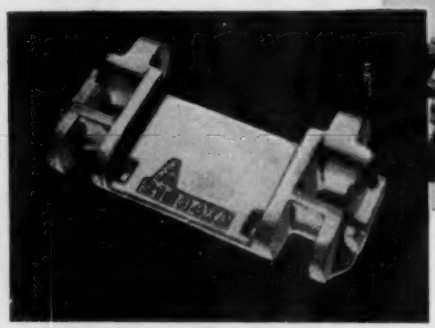
"STEPS"

IN THE

RIGHT

DIRECTION . .



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SPECIFICATION STEEL CASTINGS

Brittleness of Cr . . .

ing factor. This applies to interstitial as well as to substitutional alloying additions. The solvent-solvent, solvent-solute and solute-solute force fields are discussed, from which emerges the postulate that the transition temperature is that temperature at which the interaction force field is sufficiently weakened to allow deformation to take place. Atomic size was considered and found to have no effect on the transition temperature behavior; neither did the total number of electrons per atom, nor the position of the atoms in the body-centered cubic lattice. It is hoped that this type of experiment and analysis will be extended to other body-centered cubic metals and their alloys to prove the generality of the conclusions.

F. FORSCHER

A New Titanium Sheet Alloy

Digest of "Evaluation of a New Titanium-Base Sheet Alloy, Ti-4Al-3Mo-1V", by R. S. Richards, D. L. Day, and H. D. Kessler, ⊜ Preprint No. 45, 1957.

A TITANIUM-BASE ALLOY was evaluated on the basis of annealed, solution treated, and solution treated and aged properties. It possessed ultimate tensile strength of 170,000 to 180,000 psi. at room temperature and possessed good strength and stability under stress in the heat treated condition up to temperatures of 800° F.

Based on previous experience, the nominal composition of Ti-4Al-3Mo-1V was given an extensive evaluation by performing stress-stability tests, cold rolling, welding, and actual forming of parts in the solution treated condition.

The testing program revealed the optimum solution temperature to be 1550 to 1650° F. to give a solution treated sheet with 140,000 psi. ultimate tensile strength, 85,000 psi. yield strength, 13 to 18% total elongation, 8 to 11% uniform elongation and 2.5 to 3.0 T bend radius. Aging at 900° F. for 24 hr. gave a material with 195,000 psi. ultimate strength, 165,000 psi. yield strength, and 6 to 10% elongation.

(*Continued on* p. 216)

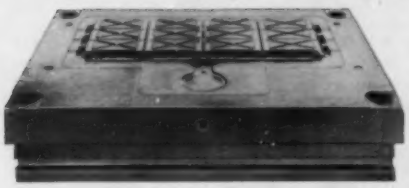
Teamed up to lick a tough job *ECONOMICALLY!*

Latrobe's . . . VDC *and pre-hardened* VISCOUNT 44

Die Casting Die Steels

Rack for assembling electronic parts (approximately 2 feet long by 1 foot wide and weighing 2.05 pounds) produced for Northrop Aircraft, Inc., Northrop Div., Hawthorne, Calif.

Harvill Corp., Los Angeles, Calif. had to produce this part DEAD FLAT at a minimum cost . . .



The problem of producing this die casting die at a minimum cost was a natural for Latrobe's VDC and Viscount 44 die casting die steels.

The die parts, not affecting the critical flatness, were made of Latrobe's VDC die casting die steel, an air-hardening, 5% chromium die steel possessing excellent machinability and superior resistance to wash and heat checking. For the die parts demanding dead flatness, the use of Latrobe's Viscount 44 prehardened die casting die steel eliminated all possibilities of warpage from heat treatment and subsequent costly grinding time to correct warpage. Die surfaces were machined to exact size! Heat treat was eliminated!

Latrobe's Viscount 44 is an air hardening, 5% chromium die steel containing 1% vanadium that imparts excellent physical properties for hot work applications. Furnished prehardened, in a range of Rockwell C 42-46, Viscount 44 is practical to machine in its prehardened form as a result of the alloy sulphides it contains. Years of experience in the production of DESEGATIZED® steels have made it possible for Latrobe to uniformly distribute these free-machining sulphide additives throughout Viscount 44.

Use Viscount 44 for your next critical die casting application. Your nearest Latrobe representative will be pleased to give you complete data . . . and warehouse stocks are available for immediate delivery.

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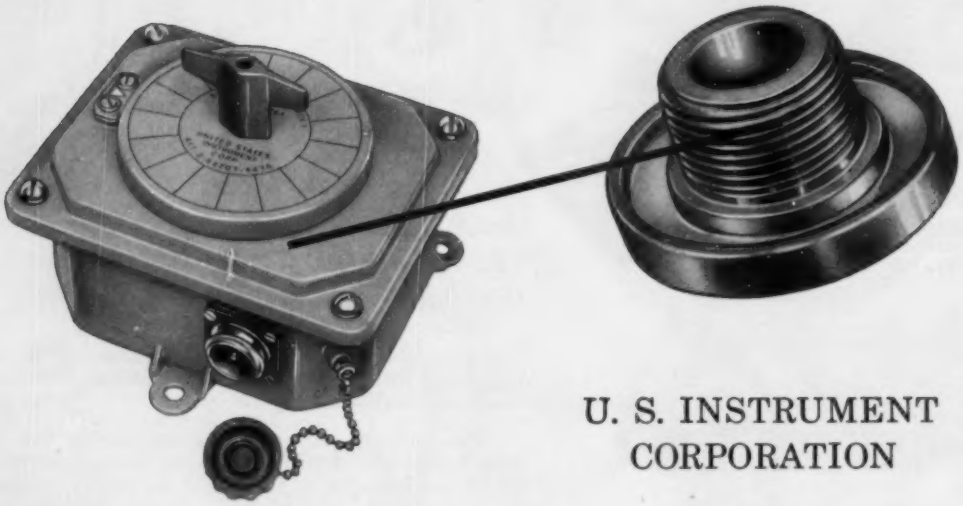
Three more nationally known manufacturers select Mueller Brass Co. Forgeable Bearing Alloys for vital components of their products

In ever-increasing numbers, Mueller Brass Co. specialized alloys are being specified by manufacturers of top-quality products. In a series of continuing advertisements, we have presented case histories of successful applications, to which we now add three more distinguished companies who are incorporating Mueller Brass Co. forgeable bearing alloys in their products to meet the demands of widely divergent operating conditions.



U. S. INSTRUMENT CORPORATION

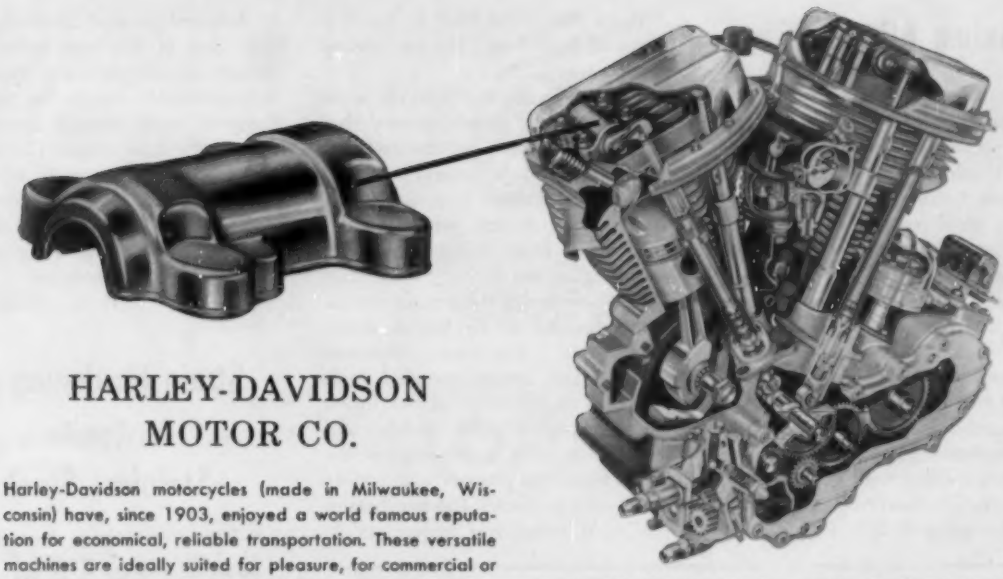
U. S. Instrument Corporation, Charlottesville, Va., selected abrasive-resistant Mueller bronze alloy bushings for their remarkable telephone selector switches after exhaustive tests of many materials. A vital communications link on today's U. S. Naval vessels, these sound-powered telephone circuits must meet rigid Navy performance-standards. Such phones, for example, must have selector switches which are capable of rotating for a minimum of 50,000 torturous cycles . . . 360° clockwise, followed by 360° counter-clockwise. In addition, the "O" ring must still form a water-tight seal AT THE END OF THE TEST! Of the many tested, a Mueller Brass Co. special manganese bronze alloy was the best one meeting these rigid specifications.

There were other important reasons why these bushings were chosen by U. S. Instrument Corporation for this application. Resistance to abrasive action against the rubber "O" ring was a prime one . . . then, too, the stem assembly suffered severe pounding through the action of the indexing mechanism which, prior to the use of the Mueller Brass Co. alloy, caused repeated seizure of the component parts. In this particular application, the part was fabricated on an automatic screw machine rather than produced as a forging. The versatility of Mueller Brass Co. alloys makes them readily adaptable to the most economical method of fabrication dependent upon the size, shape, and end-use requirements of the part.

In commenting on the success of this part, U. S. Instrument Corporation praised the alloy for its tensile strength (ordinary brasses could not withstand the 2000 ft. lb. impacts without deformation), for its machinability and corrosion-resistance.

40

MUELLER BRASS CO.



HARLEY-DAVIDSON MOTOR CO.

Harley-Davidson motorcycles (made in Milwaukee, Wisconsin) have, since 1903, enjoyed a world famous reputation for economical, reliable transportation. These versatile machines are ideally suited for pleasure, for commercial or business use, as well as the grueling demands of law enforcement work. Harley-Davidsons boast a dependable engine . . . one which can roll up an astounding mileage record with little or no care. The painstaking selection of every engine component is one important reason for this reliability. The new twin-cylinder Harley-Davidson 74 OHV employs Mueller Brass Co. bronze alloy forgings in the form of rocker-arm bearing caps. Subjected to violent temperature changes, fast starts and stops and road shock, Mueller forgings are proving again and again that they have the ability necessary to withstand almost any punishment . . . and still provide unfailing service.

JACOBSEN MFG. CO.

Jacobsen Mfg. Co., Racine, Wisconsin, was among the first to produce a practical power mower for home use. That was more than 35 years ago! Today, Jacobsen power-mower dependability is evident itself in more than a dozen gleaming new models such as the popular Pacer, Lawn Queen, Manor and others. One of the most reliable components in the always dependable Jacobsen hi-torque engine is a Mueller Brass Co. connecting rod forged from special bronze alloy. Jacobsen mowers with Mueller-forged connecting rods are called upon by some commercial users to operate as much as 8 hours daily, 6 days a week . . . perhaps as much as 2000 hours a year. In searing summer temperatures, thru hours of constant operation, the high uniform strength of Mueller bronze forgings constantly withstands pounding and vibration with the same conspicuous success as in its many other applications.

Why not investigate these specialized alloys for your own products. We welcome your inquiries. Our engineering staff will be happy to make specific recommendations. Both on the proper alloy and the best method of fabrication to meet your needs . . . exactly. Our engineering manuals show many, many examples of how American manufacturers have used these alloys to great advantage.

• WRITE TODAY FOR THE ENGINEERING MANUAL YOU NEED

- Mueller Brass Co. Forgings Engineering Manual H-58565 ☐
- Tuf Stuf Aluminum Bronze Alloys Engineering Manual H-58563 ☐
- "600" Series Bearing Alloys Engineering Manual FM-3000 ☐
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227

P O R T H U R O N 2 8 , M I C H I G A N

Titanium Alloy . . .

The elevated-temperature tensile properties of the fully heat treated sheet indicated a smooth decrease in all values until at 800° F. an ultimate tensile strength of 130,000 psi., a yield strength of 90,000 psi. and an elongation of 7% were reached.

Stress stability tests indicated that for a sheet solution heat treated at 1550° F. and aged 12 hr. at 900° F., the total plastic deformation in 1000 hr. at 800° F. and 50,000 psi. stress averaged 1.2%. This indicated that the material possessed good creep resistance along with good stability. Tests on fully heat treated specimens (24 hr. aging at 900° F.) indicated that for 300 hr. at 800° F. under a stress of 50,000 psi., the total deformation was 0.15%.

Limited formability tests on larger solution treated sheets showed that the material bent satisfactorily at room temperature around a radius of 4.0 T and that it could subsequently be stretch wrapped and joggled at room temperature with encouraging results.

Inert-arc welds were made and at first appeared to be bright, shiny, sound and nonporous: however, pickling and testing revealed voids or pores at the edge of the fusion zone. Practically all tensile and bend tests failed at the edge of the fused zone, and porosity was evident in all such failures. The hardness of the weld metal was approximately 30 diamond pyramid numbers higher than that of the base metal. Although the comparison of weld data is questionable due to the porosity, the weld metal strength approaches that of the base material and quite possibly would exceed it if the porosity could be eliminated. In general the Ti-4Al-3Mo-1V sheet is not readily weldable using present fusion welding techniques.

D. L. McElroy

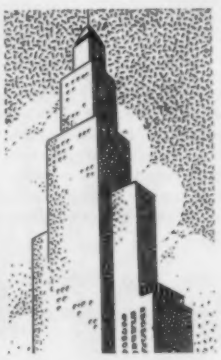
Strain Hardening of Austenitic Stainless Steel

Digest of "Strain Hardening of Austenitic Stainless Steel", by G. W. Powell, E. R. Marshall and W. A. Backofen, ASM Preprint No. 10, 1957.

It has been known for many years that steels which are austenitic at room temperature may be partially or wholly transformed to martensite if they are strained sufficiently at low temperatures. The degree to which the austenite must be strained before the transformation occurs depends on the composition of the steel and on the temperature at which the straining takes place.

In this paper the authors consider two other factors, namely, the method of straining, whether it is by tension, compression, or torsion; and the rate of straining.

Stainless Types 301 and 302 were selected for this investigation. The M_s temperature of the 301 steel was between −49 and −85° F., whereas that of 302 was below −441° F. Straining was produced by tension, compression, and torsion at temperatures from 68° F. down to −320° F., and the straining rates used were



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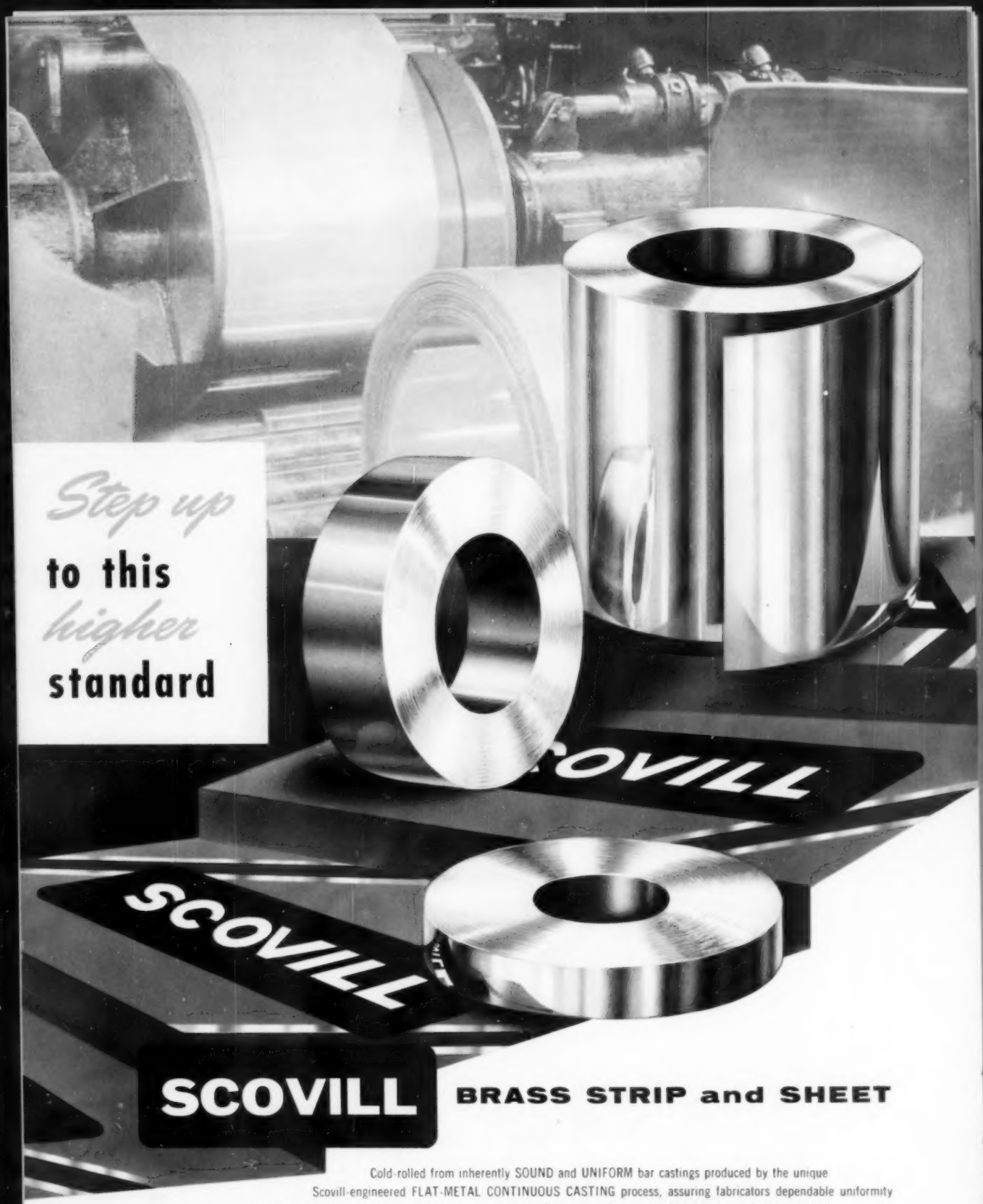

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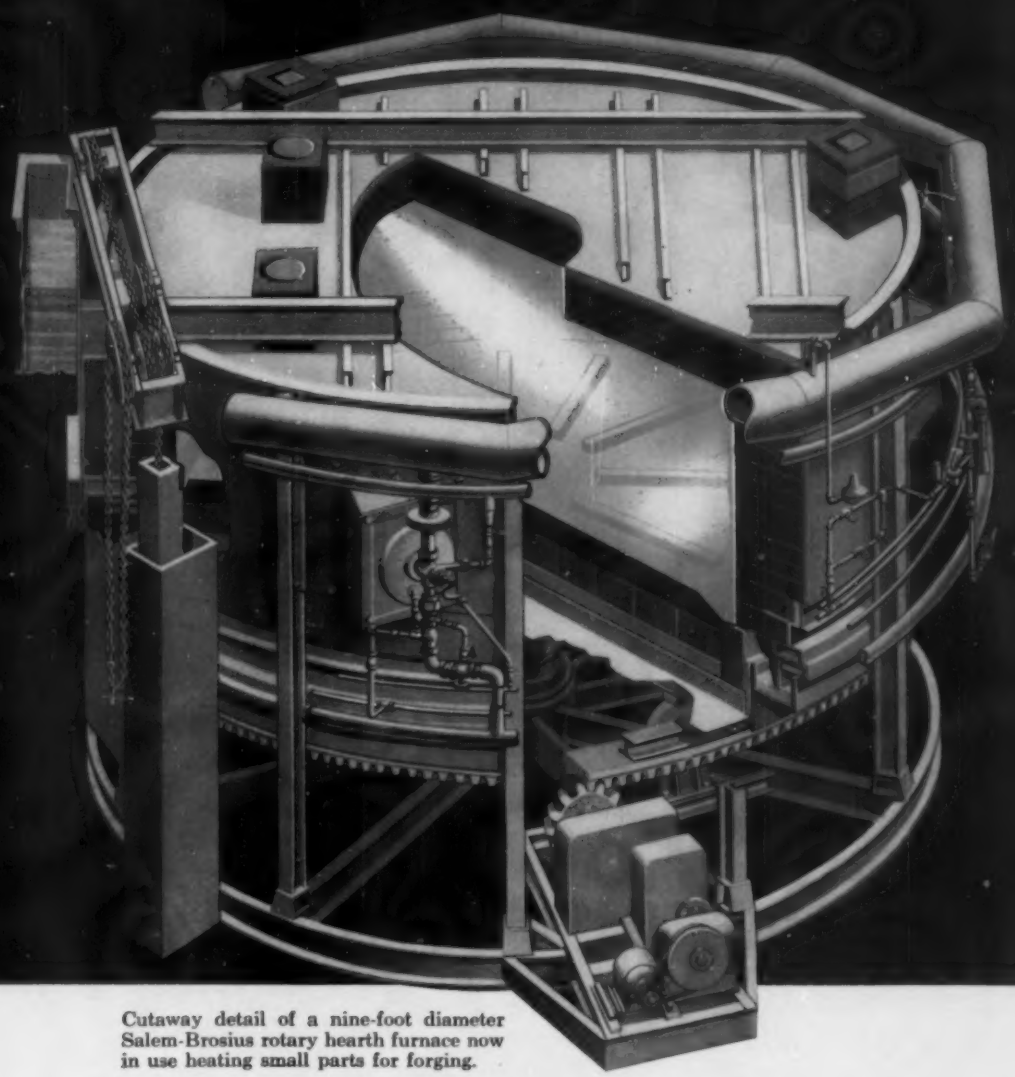

Cutaway detail of a nine-foot diameter Salem-Brosius rotary hearth furnace now in use heating small parts for forging.

This Salem-Brosius rotary furnace in your forge shop saves you money

Companies producing parts for aircraft, automobiles, farm machinery, home appliances and a host of other products find the most economical and efficient furnace they can use to heat parts for production forging is the rotary type shown here. Burners are tangentially placed, and the heat is accurately controlled and uniformly distributed throughout the furnace chamber. The speed of rotation may be varied and is precisely set to the need of the product.

There is no practical forge heating method known that can equal the high production, low maintenance, low fuel cost, and uniformity of product heating of these specially designed rotary hearths. Salem-Brosius has designed and built more rotary hearth furnaces than any other company in the world. Write to us for further information.

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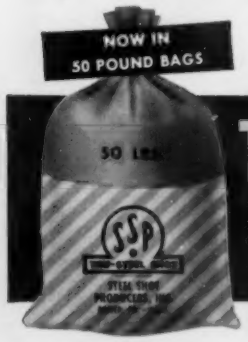

TRU-STEEL SHOT

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Strain Hardening . . .

between 0.006 and 0.6 in. per in. per min. Some tests were also made at the extremely low temperature of −441° F.

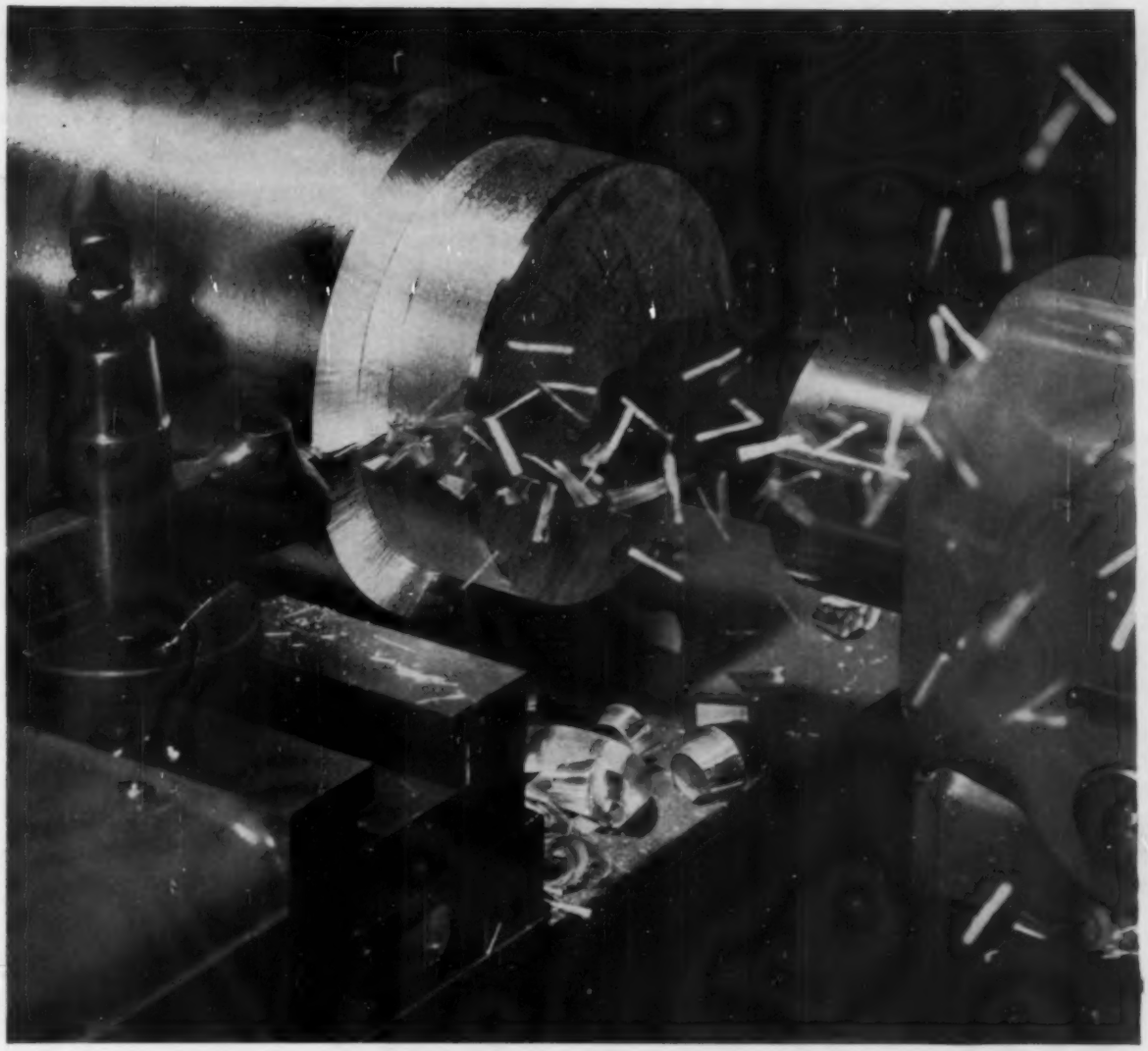
The progress of the martensite transformation was determined by precise density measurements. After the test piece had been strained by either tension, compression, or torsion, a specimen was machined from the gage section of the test piece and its density was measured. The amount of martensite produced during the straining was calculated from the density value.

Curves are presented showing stress plotted against true strain for the two steels as affected by the various temperatures of straining and the various straining rates. Under test conditions which produce no transformation, as in the testing of Type 302 at room temperature, the stress-strain curve has the conventional parabolic form. When transformation does occur, there is a rapid rise in stress for the first small increases in strain, and then a more gradual increase in stress as the amount of strain increases.

At the extremely low temperature of −441° F., both Types 301 and 304 exhibited a discontinuous stress-strain curve in the part of the curve beyond the yield stress. The serrated curve produced when these steels were strained at this very low temperature is attributed to successive steps of instantaneous softening caused by the heat of transformation, followed by hardening steps. During this kind of straining the test piece necks down in several spots within the gage section.

The effect of strain rate on the martensitic transformation was not consistent. At 68° F., martensite formation increased with increase of strain rate from 0.006 to 0.060 in. per in. per min. but at faster strain rates, the rate of martensite transformation decreased. This decrease in martensite formation with increase of strain rate is attributed to a temperature effect produced by the rapid rate of straining.

The type of strain was found to affect the transformation to some degree. Tension was more effective than either compression or torsion in producing martensite from unstable austenite. P. PAYSON



Speed! Of all structural metals, Magnesium costs less to machine

In the picture above, a lathe is making a roughing cut of 0.800" in an eight inch magnesium billet. The feed is 0.030 inches per revolution at a speed of 630 feet per minute. In finishing operations, cuts of 0.500" can be made with a feed of 0.003 ipr and a speed of 5,000 fpm.

That's real speed and efficiency—the kind you can always expect when you machine magnesium. This remarkable metal can be milled, drilled, sawed, reamed, bored, planed, tapped and threaded faster than any other structural metal!

Faster machining means easier machining and lower cost machining. It means more production per hour and per dollar, and longer tool life.

The following table shows how well magnesium compares to the others:

METAL	RELATIVE MACHINABILITY
magnesium	1.0
cast aluminum	1.8
brass	2.3
cast iron	3.5
rolled aluminum	5.0
mild steel	6.5

Let us give you more information about the machinability of magnesium. Contact the nearest Dow sales office or write to THE DOW CHEMICAL COMPANY, Magnesium Department, Midland, Michigan, Dept. MA 1404Q.

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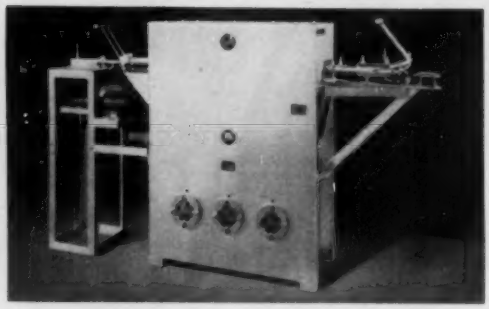
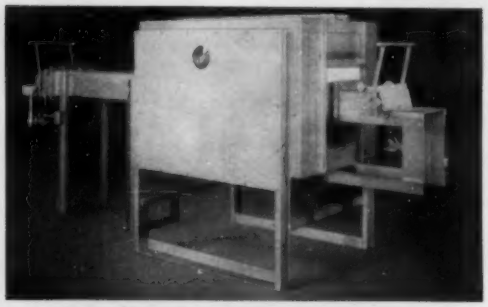
Which Sintering Furnace Do You Need?



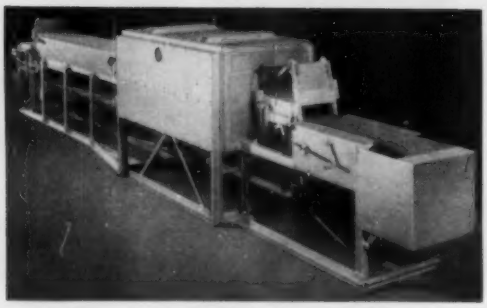
RESEARCH?

Harper Globar Tubular Element Furnaces are perfect for sintering research, with uniform heat up to 3000°F. Fast heat-up, suitable for many atmospheres, low in cost.



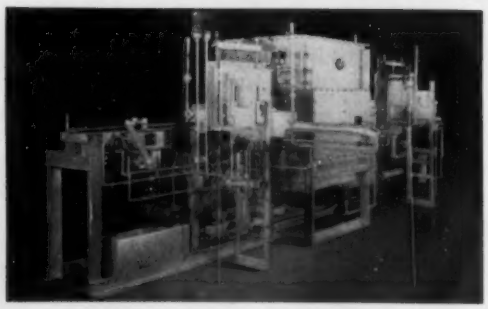
PILOT PRODUCTION?

Inexpensive Controlled-Atmosphere Straight-Through Pusher Furnaces, with entrance tunnel and water-cooled cooling chambers, are the ideal answer for a pilot-scale project on powdered metal parts. Temperatures up to 2100° F. Models available for batch, manual or automatic pusher operation. Wide size range.



QUANTITY PRODUCTION?

Harper Continuous Conveyor Belt and Pusher Sintering Furnaces are designed for large production. Belt Furnaces offer automatic uniform sintering of light weight parts at temperatures up to 2100° F. Pusher Furnaces can take heavy parts and permit operation to 2300° F. Both types have zone temperature control. Standard designs available for stainless steel work.



SPECIALTY SINTERING?

Other types of electric furnaces are also available for high temperature sintering of ferrites, carbides, tungsten contact points, heavy metals, and uranium oxide fuel pellets.

Whatever your sintering problem may be, give Harper engineers an opportunity to work with you.

HARPER
ELECTRIC FURNACE CORP.
40 RIVER STREET • BUFFALO 2, N. Y.

Vacuum Melting . . .

(*Continued from p.* 138)

For instance, boron as B_2O_3 is contained in the magnesia in sufficient quantities to cause a significant quantity of boron in the final product. In fact, a patch in a lining will contribute as much as 5 to 10 ppm. to the ingot, and this quantity has a significant effect on the properties of the metal. So it is becoming necessary to pay particular attention to the little things.

A rather thorough study has been made by the vacuum melting industry of the specific effects of the boron and zirconium which inadvertently enter the metal. Fortunately both of these materials (within limits) improve the rupture ductility and probably the rupture strength of the nickel-base alloys currently being used. For example a stress-rupture test on Udimet-500 (at 1650° F. and 25,000 psi.) will show reduction of area of 6 to 10% if boron-free, but this range rises proportionately with boron content to 14 to 18% at 22 ppm. boron. These same small quantities improve the workability of the ingots because of the improved hot ductility. Higher quantities cause considerable difficulty in fabrication, so close control is necessary.

Conclusion

In such a short paper as this, little more can be presented than some data on recent progress and indications of future trends. The utilization of very high vacuums during the entire process (most especially in tight furnaces with low leakage) has undoubtedly improved the qualities of "superalloys" necessary for gas turbine parts. Continuous analyses of the gases remaining in the furnace can determine the progress of the reactions and govern the time for adding the highly reactive final additions, so they alloy with the metal rather than form nonmetallic inclusions with any remaining gas. Scrap metal is likely to contain undesirable elements, and usually takes so much longer to degasify that it is usually poor economics to use it in a melt intended for severest services. The crucibles also may contribute undesirable elements, although for certain classes of alloys, a few parts per million of

new

Technical Digest on, Commercial-Grade Zirconium

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☐ Technical Digest on Commercial-Grade Zirconium.

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NEW METALS FOR INDUSTRY

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In parts like these

KENNAMETAL* K501

EQUALS the Noble Metals in Corrosion Resistance...

BETTERS them in Economy and Resistance to Wear!

In the chemical field, and also in the food, paint, petroleum, oil refining, paper and atomic energy industries, equipment components like the ones shown above are often exposed to extremely severe corrosion.

When—as often happens—the corrosive attack is complicated by excessive wear conditions, and when contamination of the batches handled must be avoided, the designer and plant engineer have a real problem in materials selections.

Kennametal K501 has proven itself an extremely effective and economical answer, as it combines a high degree of corrosion resistance with unusual wear resistance, that eliminates frequent replacement, and greatly reduces contamination.

Laboratory tests show no measurable weight loss of a K501 sample after five days in boiling 5% HNO_3 and 5% H_2SO_4. Loss was only 74/mg/dm/day in boiling 5% HCl.

Hardness, RA is 91.0 minimum; transverse rupture strength is 125,000 psi minimum; and, density is 15.10 minimum. The material can be formed from powders to very close tolerances, and then ground to finishes that have proved adequate in seal applications demanding a flatness of two light bands, and a surface roughness of about one microinch rmp.

If you have use for valve parts, balls and seats, guides, wear rails, slitting and cutting parts, non-lubricated guides and bushings, metering orifices, sealing rings, in applications where corrosion and wear are problems, ask for full information about Kennametal's K501. Just write: KENNAMETAL INC., Dept. CE, Latrobe, Pennsylvania.

*Trademark of a series of hard carbide alloys of tungsten, tungsten-titanium and tantalum.

C-3067

INDUSTRY AND KENNAMETAL ...Partners in Progress

Vacuum Melting . . .

boron (a common contaminate) does more good than harm.

Progressive improvements in the quality of high-temperature alloys, so notable in the last five years, is by no means exhausted. Many new alloys will appear in the next few years to continue the trends already established.

Nondestructive Tests . . .

(*Continued from p.* 144)

liquid or sheet) is bonded to a reflective surface of the stressed part; polarized light is reflected from the coated surface to a reflection polariscope instead of passing through a plastic model. Seven types of portable reflection polarizers ("photostress meters") are available.

Applicable plastics are produced in liquid form or in sheets; these differ materially in their characteristics. The surface to which they are bonded must be clean and reflective. Sheets may be clear or metallized on one face; they must be uniform in thickness, free from internal stress, and of uniform strain-optical properties. Liquid plastics are applied to clean (polished) surfaces in successive layers by brushing and heating to harden until desired thickness is obtained. Sheets are preferred because they are of more uniform thickness than a brushed-on coating, and can be bonded to the surface at room temperature. However the liquid is very handy for small parts, closely spaced rivets, fillets, or recesses of small radii. Rigidity of the work piece will determine the thickness of the plastic coating needed; greater thickness will increase the sensitivity of the measurements up to a certain point.

This striking technique should be of great advantage to design engineers for both static and dynamic parts and structures. The strains may be recorded on film for detailed study. There are, of course, some limitations: The method cannot be used on locations inaccessible to light. Temperature variations during testing affect the results, since the strain-optical constants of the plastics change outside a fairly narrow temperature range (45 to 80° F.).

(*Continued on p.* 224)

AGF has "twins"

PROVEN DESIGN — The completely new AGF "Twin-Hearth" Shaker Furnace incorporates the proven and accepted design and construction features of standard AGF Shaker Hearths manufactured since 1921.

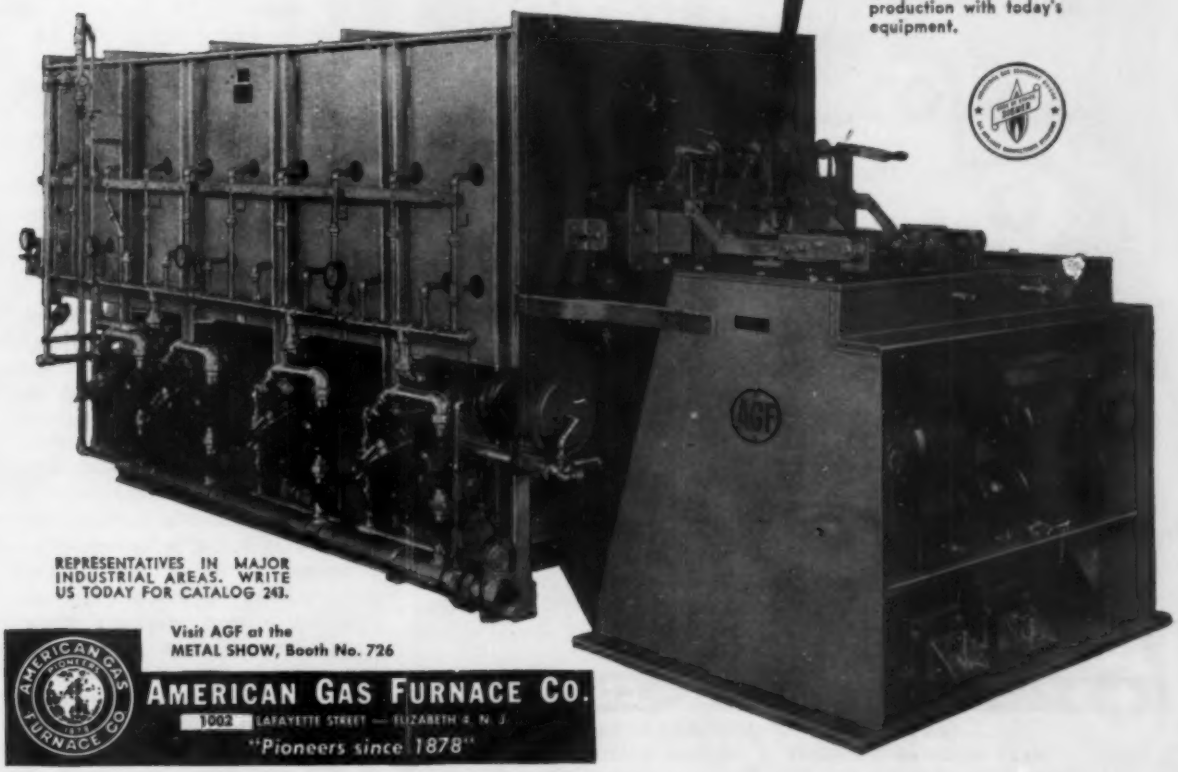
THE DIFFERENCE IS IN THE "TWIN-HEARTHS" — (each has an individually controlled drive) which permits heat treating *two different types of parts* requiring the same atmosphere and temperature, but which may require different or identical processing time cycles.

THE RADIANT MUFFLE TUBE within which the work is processed is externally heated. Many small burners accurately and uniformly heat the muffle — top, bottom and both sides. The burners are manifolded into multiple control sections for exact automatic control of the temperature of the various heating zones.

AUTOMATIC OPERATION ASSURES QUALITY CONTROL — Continuously automatic work flow coupled with exact control of processing temperature and atmosphere conditions assure that each piece receives the same identical treatment as every other piece, thus enabling a degree of scientific quality control that is unobtainable with batch type furnaces.

VERSATILITY
AGF Shaker Hearth Furnaces equipped with automatic quenching, washing and tempering systems are "Modern Production Tools" that can be incorporated into your manufacturing sequence.

"TWIN-HEARTH" Shakers are only one of the many AGF "PROVEN DESIGN" furnaces that provide you with the complete flexibility required to do tomorrow's production with today's equipment.



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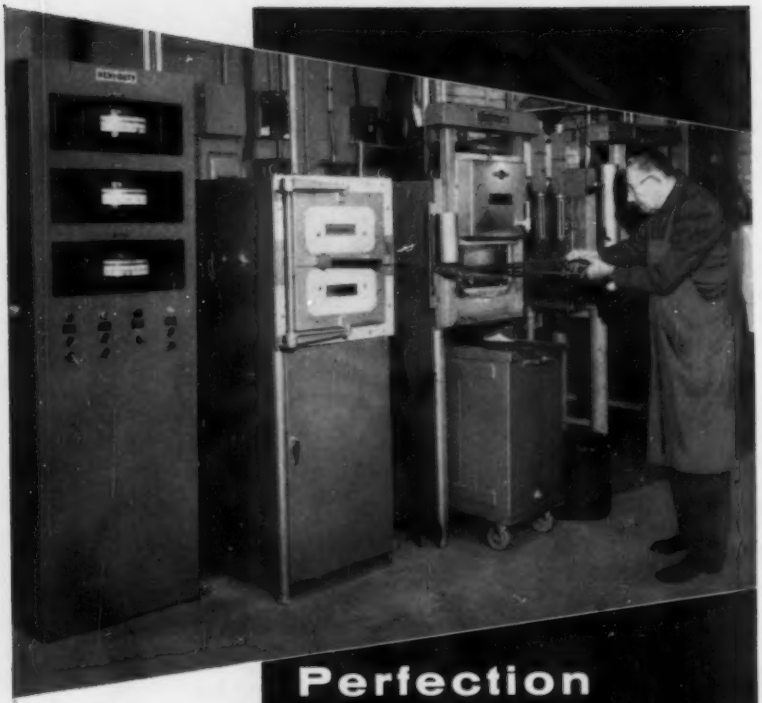

Perfection
in Heat Treatment
with this Hevi-Duty
TOOL ROOM
COMBINATION

Bert Morton, Tool Room Foreman of Sargent & Company in New Haven, Connecticut, says, "Our dies have to stand up in production runs of 100,000 and more and we find our Hevi-Duty Tool Room Combination gives us the perfection in heat treatment we need."

Sargent & Company performs all heat treating operations necessary for tools, dies, punches, special fixtures and cutters made from the complete range of tool steels such as cobalt, high chromium and carbon alloys, with outstanding success in this Hevi-Duty tool room set up.

The compact group consists of a "Treet-All" furnace, temperatures to 1850°F; "Hi-Treet" furnace, temperatures to 2500°F; "Temperite" furnace, temperatures to 1350°F; and an "Atmo-Gen" atmosphere generator.

Write for Bulletins 1147 A-B-C-E for complete information.

HEVI-DUTY ELECTRIC COMPANY

MILWAUKEE 1, WISCONSIN

Heat Treating Furnaces... Electric Exclusively
Dry Type Transformers *Constant Current Regulators*

Nondestructive Tests . . .

A User's View – A. Taboada, of Oak Ridge National Laboratories, outlined the inspection practices required for very small tubing used in certain nuclear reactors. These Inconel tubes are about 3/16-in. outside diameter, and are assembled into the reactor core by complicated welding methods. Visual and fluorescent penetrants were used for detection of outside surface defects, while X-ray, eddy-current and ultrasonic equipment were tried for internal and inside defects. In all, this required five different inspection methods for each length of tubing.

His talk again emphasized the fact that most nondestructive testing is not too definite or selective in spotting a variety of discontinuities – for example, whether an internal discontinuity is an inclusion, a scratch, a change in dimension, or a variation in grain size. Successful adaptation of these methods is often possible only after the most careful regulation and calibration of the equipment. Even then it requires extensive correlation with destructive tests to know what a "pip" on the screen or a jiggle in a dancing line means.

Effect of Thermal Cycling on Growth of Uranium

Digest of "The Growth of Uranium Upon Thermal Cycling", by J. E. Burke and A. M. Turkalo, Preprint No. 17, 1957.

A MECHANISM has been proposed to explain the changes in shape that occur in uranium when it is subjected to thermal cycling between room temperature and temperatures of about 500° C. (930° F.). The authors previously applied the same mechanism to zinc.

When uranium is thermal cycled it is subjected to deformation by a thermal ratchet which has two mechanisms – crystallographic slip at low temperatures and viscous grain-boundary flow at high temperatures. Uranium is an anisotropic material with different coefficients of expansion along different crystallographic directions such that when two adjacent grains with dif-

ferent orientations are heated a tensile stress is set up in one grain and a compressive stress in the adjacent grain. Grains which are so oriented that the resolved shear stress along the slip plane is greatest are considered the weaker grains, and these are the grains which undergo slip during cooling. When the uranium is heated to a sufficient temperature that grain-boundary flow is viscous, the shear stress between the two grains is relaxed with accompanying grain-boundary deformation. During cooling, the stress is reconstituted and slip occurs in the weaker grain to accommodate for the stress. On reheating, the elastic tensile stress in the weaker grain decreases, becomes zero again at the higher temperature, and is replaced by a compressive elastic stress which is relaxed by grain-boundary flow. On cooling the ratchet is repeated.

The deformation in uranium during thermal cycling is dependent upon the texture of the material. Uranium rolled in the alpha field has a strong texture in which the [010] direction is along the rod axis. This results in a pronounced elongation during thermal cycling. The predominant slip system in uranium is (010) [100]. Thus, the grains with the preferred orientation are the stronger grains and will grow at the expense of weaker grains less favorably oriented. If the uranium is heated in the beta field, it develops a random orientation and very little distortion occurs during thermal cycling. This is because the algebraic sum of all distortions is almost zero.

No deformation occurs if the elevated temperature is below 350° C. (660° F.), because little or no grain boundary relaxation can occur under these conditions.

If the rate of cooling from the elevated temperature is very much greater than the rate of heating, the amount of deformation is less than it is the other way about. The reason for this is that slow cooling in effect lowers the temperature at which viscous grain-boundary flow occurs and amounts to cycling at a lower maximum temperature.

Composition also is effective in altering the amount of deformation. It was shown that carbide inclusions which hinder grain-boundary flow decrease the growth rate in thermal cycling.

ROBERT JAFFEE

100% INCREASED OUTPUT

OPERATING COSTS CUT 50%

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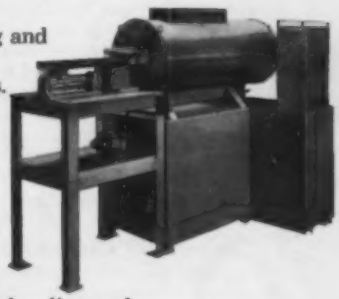
Hevi-Duty

SHAKER HEARTH FURNACE

These facts are reported by William T. Courtney of the Courtney Heat Treating Company, in Cuyahoga Falls, Ohio.



This firm has been neutral hardening and carbonitriding springs and rasps of stainless steel, spring steel and alloys. Production has increased from 45 to 50 pounds per hour to 90 to 100 pounds per hour. Maintenance costs have been reduced, there is an exact duplication of quality, and the furnace has the ability to do several heat treating jobs. In addition, they like the ease of operation and handling of parts, the cleanliness of operation and the positive control of temperature.

If you bright harden, carburize, or cyanide small parts, write for Bulletin 850 to see if the Hevi-Duty Shaker Hearth Furnace can save you time and money.

HEVI-DUTY ELECTRIC COMPANY

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Heat Treating Furnaces... Electric Exclusively

Dry Type Transformers *Constant Current Regulators*

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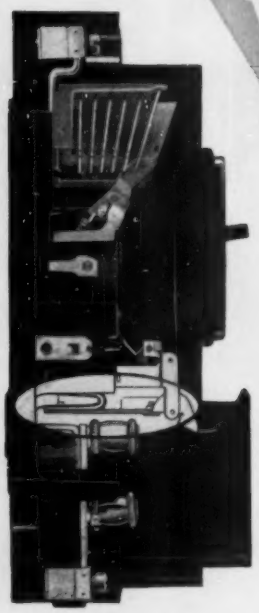

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The Westinghouse TRI-PAC Circuit Breaker was developed to provide an economical high-interrupting capacity device for protection against short circuits, or fault currents, in applications delivering up to 100,000 amperes to breaker locations. This advanced-type breaker gives *triple* protection - (1) thermal time delay, (2) magnetic instantaneous, and (3) fusible current limiting. Developed by Westinghouse research engineers, this combination is greatly superior to fuses alone. Expensive fuse-replacement is reduced and single-phasing is eliminated.

With a world-wide reputation for reliability of products, it is natural that Westinghouse should rely on Chace to provide the all-important thermostatic bimetal breaker element. Precision-formed to the finest tolerances in the industry, Chace Thermostatic Bimetal is rigidly tested and inspected by experts with over a third of a century of exclusive bimetal specialization. With unerring and automatic precision, these vital elements initiate the breaking of the circuit when fault currents endanger valuable equipment. *Made* better to help industry's products *perform* better, Chace Thermostatic Bimetal continues to widen its usage in applications everywhere, year after year.

Remember Chace when you design for protection of valuable equipment or for temperature actuation or indication. Dependable Chace Thermostatic Bimetal is available in 28 types, in strip, coil, or completely fabricated and assembled elements made to your specification. (We do not manufacture complete controls or any other devices in competition with our customers.) Write today for new 44-page booklet, "Successful Applications of Chace Thermostatic Bimetal", containing interesting uses of bimetal and many pages of engineering data that may help you solve your product problems.

IT BENDS WITH THE HEAT

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1626 BEARD AVE., DETROIT 9, MICH.

Grain Growth and Recrystallization Studies on Titanium

Digest of "Grain Growth and Recrystallization Studies on Commercial Titanium, RC-55 and Alloy Ti-100 A", by E. L. Bartholomew, Jr., Preprint No. 1, 1957.

EXTENSIVE FABRICATION of titanium and its alloys by cold forming methods is anticipated. The required annealing operations may occasionally lead to crystal sizes which might be prohibitively large. For this reason the influence of grain size prior to deformation, of amount of cold deformation, and of annealing temperature and time, on the final grain size of titanium RC-55, and a titanium alloy, Ti-100 A, was investigated.

Some scatter of datum points was found in the deformation range between the critical deformation and about 20% deformation, but this was largely due to partial coarsening of the crystal size. A typical peak crystal size of 0.15 mm. was found by annealing RC-55 which was cold rolled to 7% reduction, for 1½ hr. at 1500°F. As might be expected, the peak crystal size of both alloys was influenced by the temperature and time of anneal as well as the amount of deformation. However, the use of a single curve to represent the grain size as a function of these variables above 10% reduction suggests that the resulting grain size is a function of deformation only. As a result of annealing critically deformed RC-55 and Ti-100 A, grain boundaries were curved and highly irregular, which suggests that strain-induced boundary migration could be the mechanism by which the coarse grains are developed.

A series of large-grained RC-55 specimens were rolled and annealed but no significant coarsening was observed. At deformations above 20%, grain refinement was found along with evidence of recrystallization. These results indicated that the original grain size could be large enough to preclude coarsening at deformations less than those resulting in recrystallization and so subsequent studies were made on Ti-100 A and are reported.

(*Continued on* p. 230)

SUCCESSFULLY BRAZED WITH

Here's a brazing job that was no easy problem. It is being done now successfully thanks to the engineering ingenuity of Southwestern Engineering Company personnel. This is a "first" for this type of brazing operation on the West Coast. Twenty-four of these heat exchangers are already in service in Texas oil fields and many more will follow.

The tube sheets are for large diameter exchangers. Brass plate, 3/8" thick, is brazed to 3¾" thick steel plate with .005 x 6" Silvaloy 45 and APW Black Flux. Furnace heating was used.

Silvaloy Brazing Alloys and APW Fluxes are helping to speed production, lower costs and improve brazing results in many fields. Call your nearest Silvaloy Distributor for information or technical assistance. ★ ★

SWECO

SOUTHWESTERN ENGINEERING COMPANY

Southwestern Engineering Company, designers and manufacturers of heat exchangers, pressure vessels and special fabricated equipment for the process industries. ★ ★ ★ ★

Two complete reference manuals for low temperature silver brazing and fluxing are available upon request. Send for either one or both. ★ ★ ★ ★

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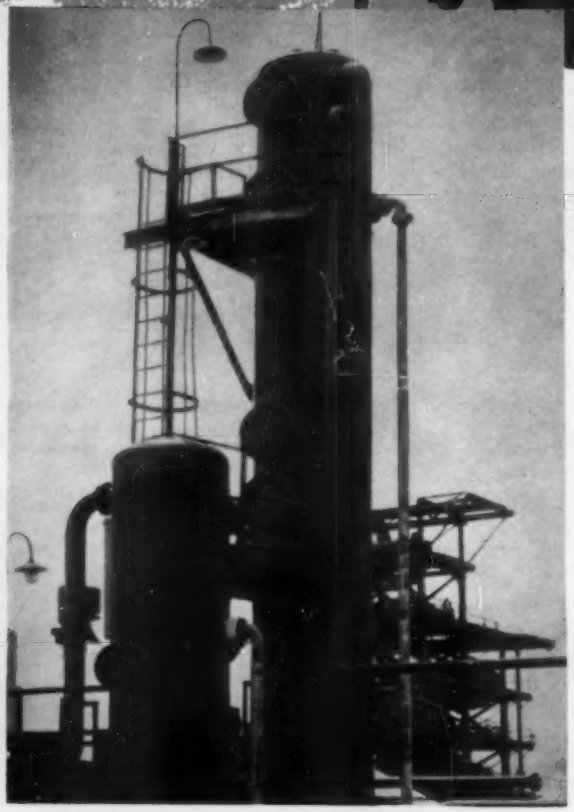

CORROSION

HASTELLOY Alloy B has a service life 30 to 40 times that of ordinary materials while handling highly reactive hydrogen chloride gas at a chemical plant.

In petroleum, chemical, or food processing industries—wherever you find highly corrosive conditions—HAYNES Alloys are long-wearing and most economical.

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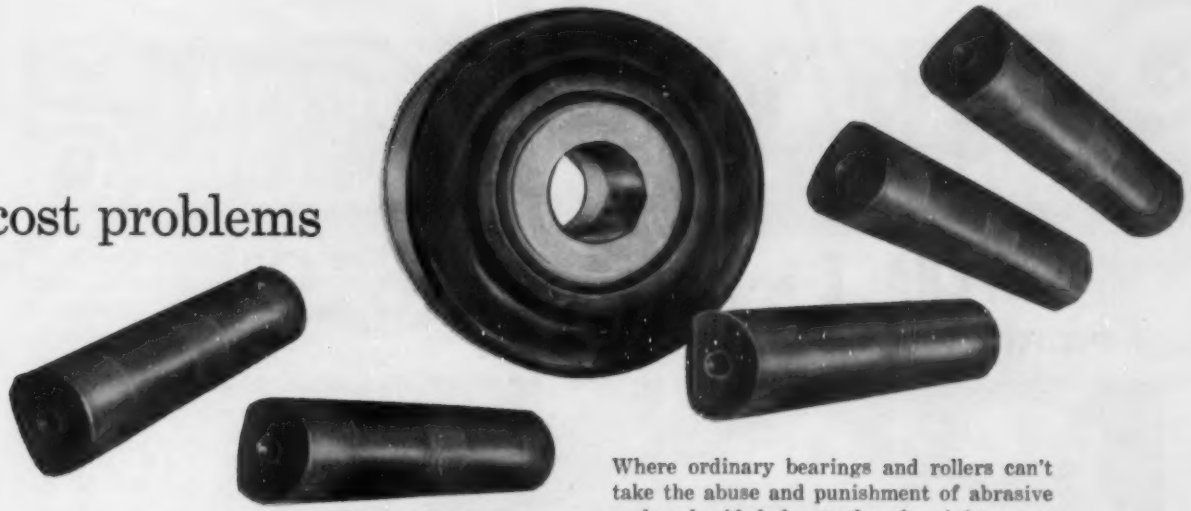
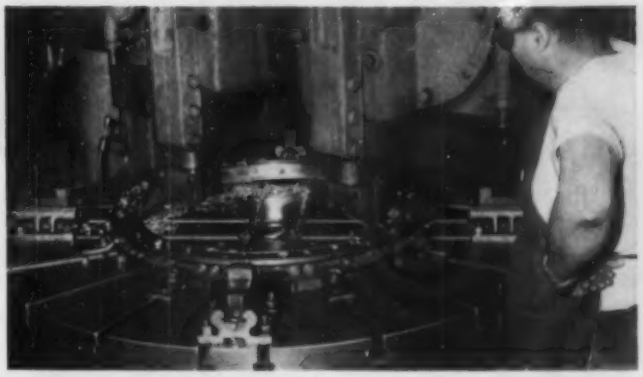


ABRASION

Where ordinary bearings and rollers can't take the abuse and punishment of abrasive rock and acid sludge, such as in mining operations, they are hard-faced with HAYNES STELLITE Alloy No. 6 and last for years instead of weeks! HAYNES Alloys reduce maintenance and replacement costs by giving long service.

Wherever you have a *tough* cost problem due to maintenance or replacement expense caused by excessive wear, heat, or corrosion, or where there is a complex design or production problem—investigate the use of HAYNES Alloys.

In practically every industry, you will find HAYNES Alloys helping to increase production and reduce maintenance—doing an efficient job at low cost. For information on HAYNES Alloys, contact our nearest sales office or write HAYNES STELLITE COMPANY, Division of Union Carbide Corporation, General Offices and Works, Kokomo, Indiana. Sales Offices in Chicago, Cleveland, Detroit, Houston, Los Angeles, New York, and San Francisco.



MACHINING

HAYNES STELLITE 98M2 alloy tools remove metal fast in machining jet engine diaphragm rings. These tools take a ½-in. cut and remove 55 cubic in. of metal in 15 minutes. About six rings now are machined per grind where other tools failed to finish even one. And tool service life has jumped over 600 per cent. Fast, precision machining with long tool life makes a big difference in production costs.

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ALLOYS
HAYNES STELLITE COMPANY
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AVERAGE and ATLAS

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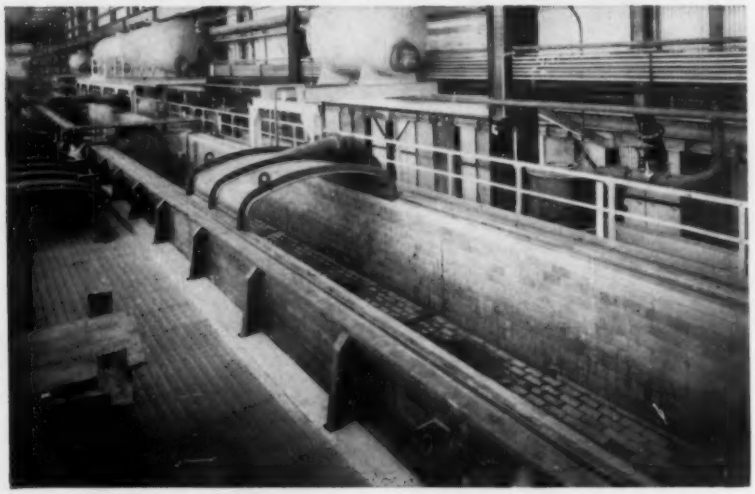

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Since Atlas installed the first continuous brick-lined pickler in 1933, more than 10,000,000 pounds of Atlas corrosion-proof materials of construction have been used to build all types and styles of pickling tanks throughout the world. The huge pickling tank pictured above was recently installed in a large eastern steel mill and is a typical example of Atlas design and construction in the metalworking field.

Experience has taught us a successful pickling tank requires an integrated combination of highest quality materials, tested and proven design, expert and craftsman-like construction. Only Atlas offers such a service ...a sole source of responsibility, standing behind their installation, controlling every step of the job, from the basic manufacture of the products to the final use of the material.

Why choose the average when you can benefit from the BIG difference of an Atlas pickling tank? One that will be a permanent asset... deliver full service... withstand the rugged abuse of modern pickling operations and not be hampered by down-time for repair of corrosion damage. Make sure you specify ATLAS for your next installation.

Write for Bulletin CC-3 giving complete information on the Atlas line.

ATLAS MINERAL PRODUCTS COMPANY
MERTZTOWN, PENNSYLVANIA

Grain Growth in Ti . . .

Cold rolled RC-55 was isothermally annealed to verify the evidence of grain growth without recrystallization. Isothermal recrystallization data for 12% and 30% reduction annealed at 1100, 1200, and 1300°F. were used to obtain the times for 30, 50, and 70% recrystallization, which were then plotted as a function of the reciprocal absolute annealing temperature. The activation energies for 30 to 70% recrystallization of 30% cold rolled RC-55 are between 74 and 79 kg-cal. per mol. whereas those for 12% cold rolled are in the range 33 to 35. This difference indicates that a transformation mechanism other than recrystallization is operative in the 12% reduction and this is believed to represent the activation energy for strain - induced grain - boundary migration. This is analyzed in terms of the related thermodynamics of boundary migration.

D. L. McElroy

Magnesium-Lithium Alloys

Digest of "Deformation and Fracture of Alpha Solid Solutions of Lithium in Magnesium", by F. E. Hauser, P. R. Landon and J. E. Dorn, Preprint No. 5, 1957.

Serious limitations are imposed upon the low-temperature deformation of polycrystalline aggregates of such hexagonal close-packed metals as cadmium, zinc and magnesium by the fact that only basal slip and twinning are the normal deformation mechanisms. These limitations are held responsible for the brittle fracture behavior of zinc and the relatively low ductility of magnesium observed at low temperature.

The present research had as its objective the determination of effects on deformation capacity of magnesium produced by a number of solid solution alloying elements; results demonstrate the promising behavior of magnesium-lithium alloys.

A preliminary survey was made with magnesium alloys containing a number of alpha solid solution-forming elements selected to have as wide a range of atomic radii, valencies and effect on the axial ratio c/a as

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Full information for both instruments contained in **BULLETIN 2253-J,** *furnished on request.*

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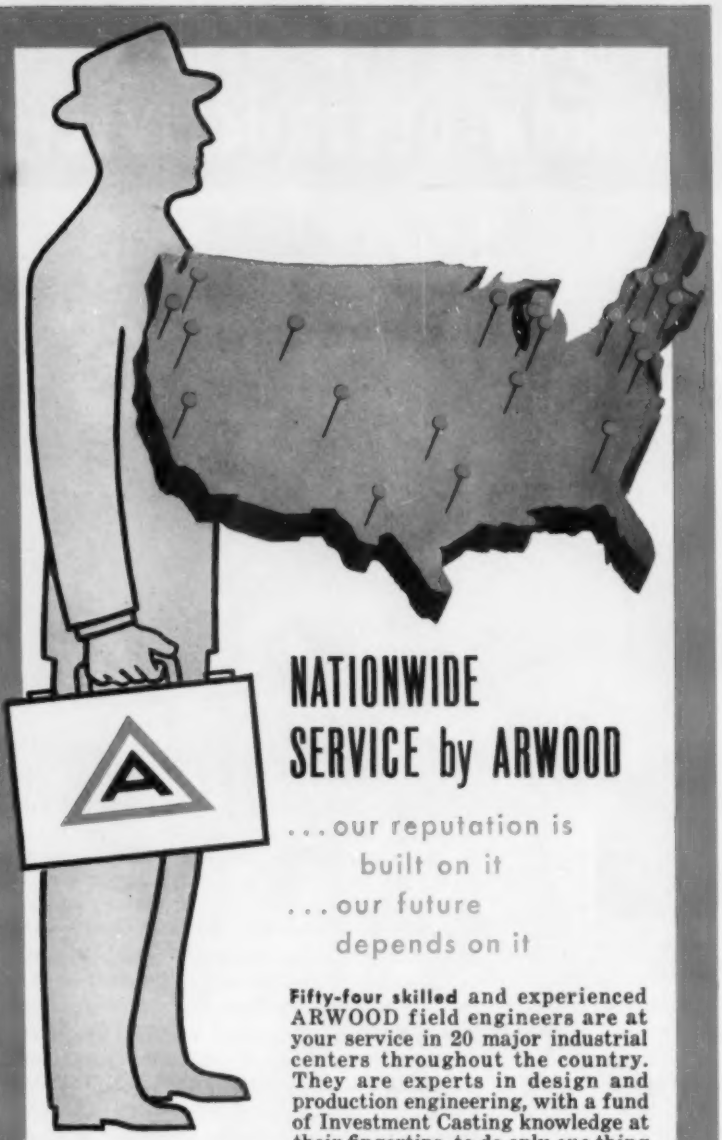

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Mg-Li Alloys . . .

possible. The results of this preliminary survey of the plastic properties and fracturing characteristics at the boiling temperature of liquid nitrogen, 78° K., indicated that major emphasis should be placed on additional study of alpha solid solutions of lithium in magnesium. The other binary compositions containing tin, cadmium, mercury, silver, thallium, indium, bismuth or aluminum were all essentially brittle, while the lithium alloy was significantly more ductile.

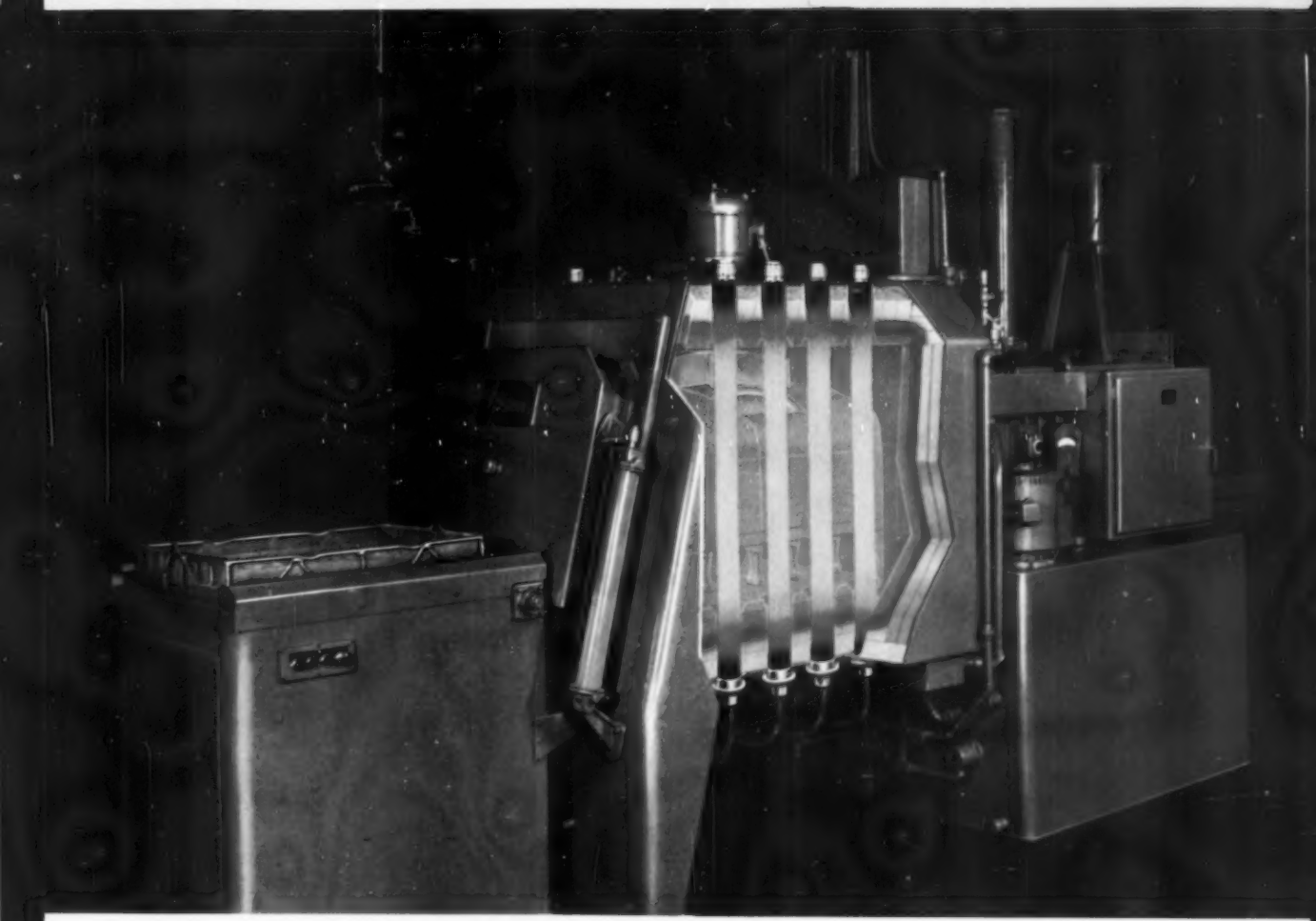
Tensile tests were then made on a series of binary magnesium-lithium alloys containing up to 14.5 at. % lithium at temperatures of 295, 195, 78 and 4° K. The studies at 195° K. showed that the stress-strain curves exhibited a change in slope with reduced strain hardening rate at lithium contents of 7.6 at. % or higher, the change in slope occurring at a lower stress the higher the lithium content. This sudden abnormal change in strain hardening rate and the associated increase in ductility to as much as four times that of pure magnesium suggested that an additional deformation mechanism was introduced by the alloying additions of lithium.

Metallographic examination and analysis of slip traces disclosed that the decrease in strain hardening rate and transition from brittle to ductile fracturing coincided with the appearance of general prismatic slip throughout some of the grains. The evidence indicated strongly that the improved ductility resulted from the availability of both prismatic and basal slip.

Correlations of the axial ratio c/a at which active prismatic slip was attained in the magnesium-lithium alloys with the ratios and the observed slip mechanisms for other metals indicated that a ratio c/a of 1.618 or higher was needed for prismatic slip to become active. The significance of the apparently critical ratio was rationalized in terms of dislocation theory.

It is anticipated that commercial interest may develop in magnesium alloys with lithium additions as structural materials based on their favorable strength-weight ratio and substantial capacity for deformation.

H. Y. HUNSICKER



look into this

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turn to next page for information on the new Ipsen Flame-Busters →

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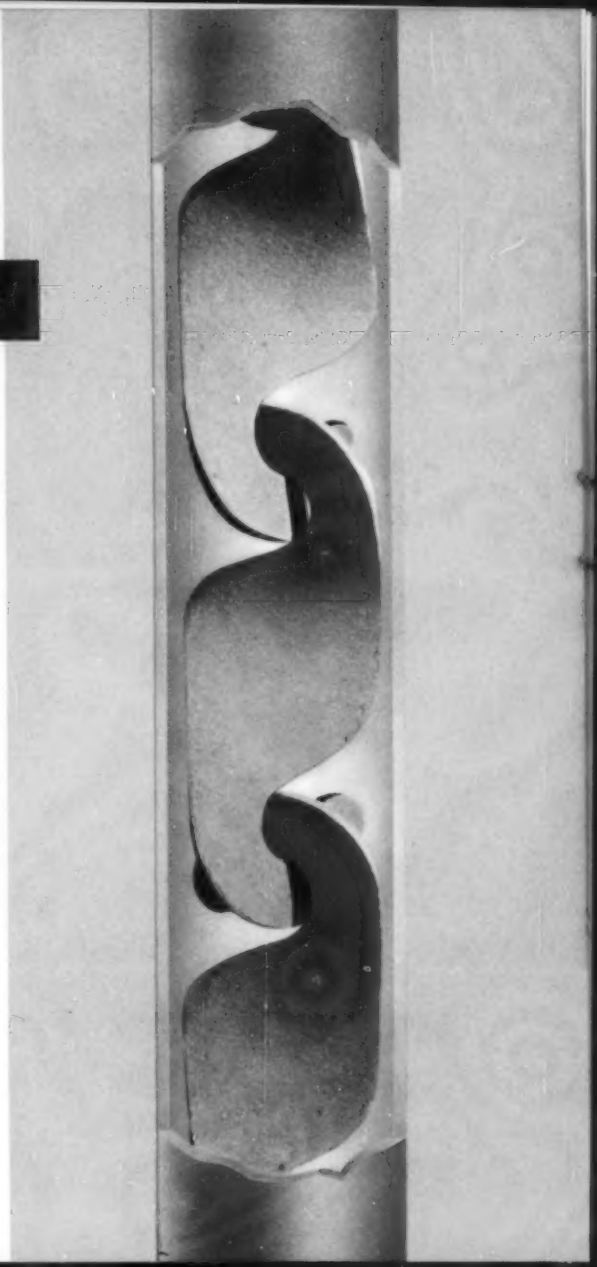

For electric operation, lift the Flame-Buster assembly from the ceramic tube, and replace it with a resistance type element. Changeover can be made quickly . . . and the elements are completely protected from the furnace atmospheres.

This cross section shows an assembly of Flame-Busters suspended in an Ipsen alloyed ceramic heating tube. Flame-Busters interrupt flame path, keep heat in tube longer, increase heat transfer.

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A New Classification for Precipitation Systems

Digest of "Classification of Precipitation Systems", by R. O. Williams, Preprint No. 13, 1957.

THREE METHODS have been proposed for classifying the many metal-alloy systems in which precipitation occurs. The first of these describes the nature of the supersaturated solid solution and the precipitate in terms of terminal solid solution, intermediate phases, and intermetallic compounds. A second distinguishes between aging behavior at relatively low and at high temperatures. The third depends on the relative size of the different atoms. These three methods the author considers inadequate and he therefore proposes a much more comprehensive scheme.

It is proposed that precipitation systems be classified according to three structural characteristics: (*a*) the degree of complexity of the nucleation, (*b*) the predominant shape of the particles of the new phase, and (*c*) the degree of order which exists within the matrix and precipitate. There are three kinds of nucleation – simple, complex, and discontinuous; four kinds of particle shapes – needle, sphere, plate, and polyhedron; and four possible combinations of order-disorder – ordered matrix-ordered precipitate, disordered matrix-ordered precipitate, ordered matrix-disordered precipitate, and disordered matrix-disordered precipitate. Thus 48 classes are possible, although few, if any, examples will be found of some of these classes.

An example of simple nucleation is a face-centered cubic precipitate in a face-centered cubic matrix. By complex nucleation is meant the process by which a phase is formed which contains atomic positions markedly different from those of the matrix – for example, the formation of a body-centered cubic precipitate from a face-centered cubic matrix. Finally, discontinuous nucleation occurs at or in the immediate vicinity of high-angle grain boundaries resulting in a new crystallographic orientation and the precipitate. The new phase frequently occurs as plates normal to the moving boundary and has an appearance much like that of pearlite.

It is the author's hope that the classification of precipitation systems will help show the similarities and dissimilarities among them, will show how the physical properties depend on structure, and how best to obtain optimum structures. A chart shows dependence of physical properties on the characteristics of precipitation systems.

Some of the more common systems are identified as follows:

Aluminum-Copper – Above 200° C. (390° F.), there is complex nucleation, disordered matrix, ordered plate precipitate. At low temperature there is simple nucleation, disordered matrix, and disordered plate precipitate; however, some data indicate a second low-temperature form in which the plate precipitate is ordered.

Aluminum-Silver – Above about 190° C. (375° F.), first a complex nu-

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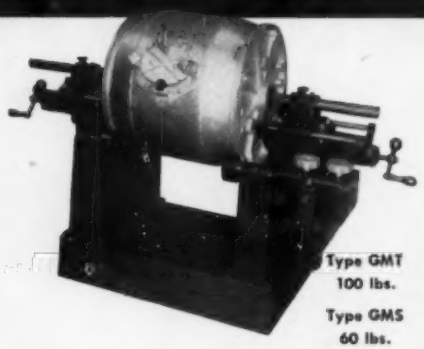

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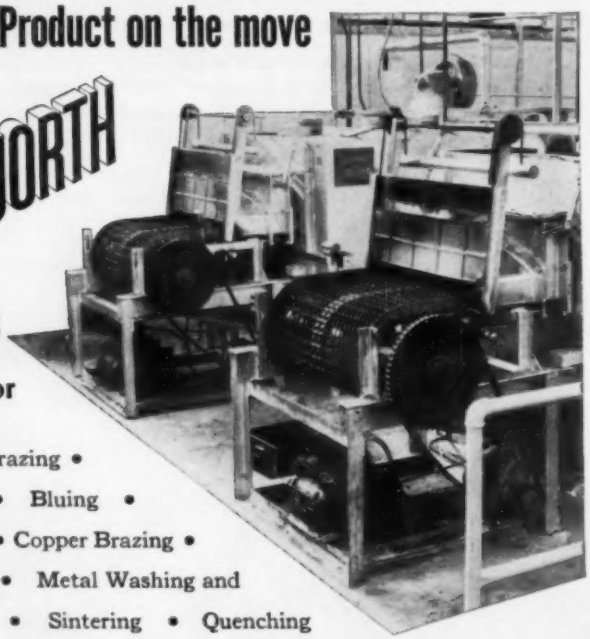

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Precipitation Systems . . .

cleation, disordered matrix, and a disordered plate precipitate, is followed by a discontinuous nucleation, disordered matrix, with disordered plate precipitate. Below 190° C. there is simple nucleation, disordered matrix, and an ordered spherical precipitate.

Aluminum-Nickel-Iron — Simple nucleation, ordered matrix, disordered plate precipitate; or simple nucleation, disordered matrix with ordered plate precipitate occurs, depending on whether the ordered Ni-Al phase is considered the matrix or the precipitate.

P. PAYSON

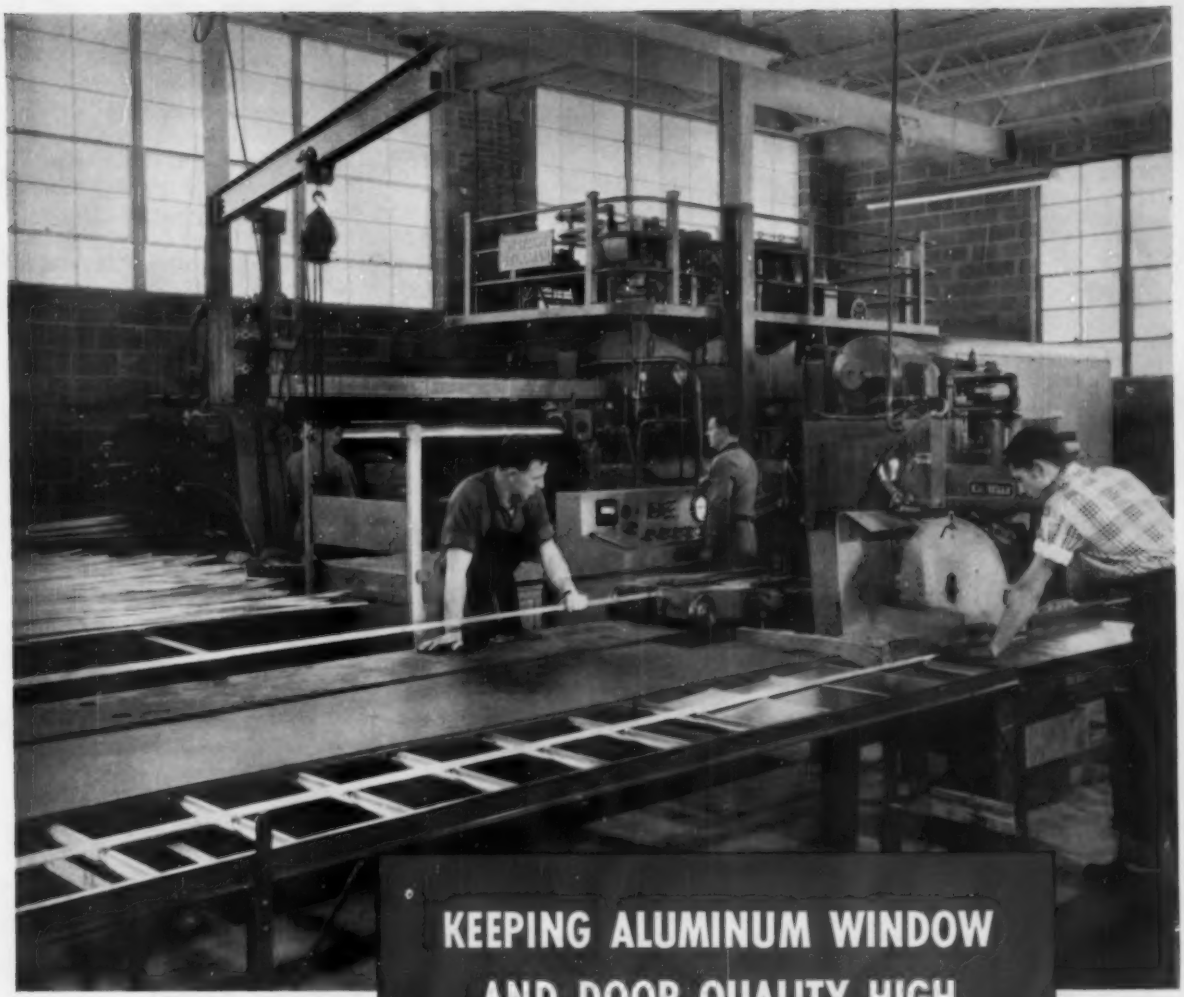
Torsional Strength and Microstructure of High-Carbon Steel

Digest of "Some Relationships Between Torsional Strength and Electron Microstructure in a High Carbon Steel", by S. T. Ross, R. P. Sernka and W. E. Jominy, Preprint No. 46, 1957.

PREVIOUS WORK by the authors has indicated that percarbide films surrounding martensite plates in tempered steel may be a cause of erratic fatigue and torsion test data at high hardnesses. Work of the A.S.T.M. Subcommittee on Electron Metallography shows that the electron microstructures of martensite tempered below 550° F. and of isothermally formed lower bainite are very similar, but that carbide films do not exist in the bainite structure. It was thus considered possible that bainite samples at high hardnesses might show less scatter in torsion test results than samples quenched and tempered to the same hardness range.

This possibility was investigated by making a series of torsion specimens from S.A.E. 51100 steel with microstructures of tempered martensite and bainite. They were compared as to torsion yield strength (calculated from the force to give 1.0° offset), torsion ultimate strength, fracture characteristics, and electron microstructure.

Quenched and tempered specimens were prepared by austenitizing



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at 1800° F. for 1 hr. and quenching in agitated oil at room temperature. All but three specimens (which were tested as quenched) were immediately cold treated at −105° F. for 30 min. and then tempered at temperatures from 400 to 600° F. for various times. Bainite specimens were austenitized and then held at temperatures from 400 to 550° F. for sufficient times (determined for this lot of steel) to transform the austenite completely to bainite. Three specimens were given each heat treatment, and the torsion test results were averages of the three. Hardness of all specimens was in the range Rockwell C-53 to 65.

The torsion yield strength versus hardness relationship is initially very similar for both microstructures, linearly increasing from about 130,000 psi. at Rockwell C-53 to almost 170,000 psi. at Rockwell C-58. Above a hardness of about 58, tempered martensite specimens behave erratically, with the only certain trend being to much lower strengths for untempered specimens at very high hardness (62 and 65). The strength-hardness relationship for bainite specimens is linear to the highest hardness studied – C-60.

Untempered martensite specimens fractured brittlely, while bainite specimens (excluding the highest hardness specimen) showed a typical shear fracture perpendicular to the specimen axis. All other specimens exhibited a fracture regarded as a combination shear and brittle failure. These bars broke into many small pieces, some of which contained shiny shear surfaces parallel to the specimen axis.

Electron micrographs were made from chromium-shadowed formvar and parlodion replicas of specimens representative of each heat treatment. Without exception, long continuous lines indicative of cementite or percarbide films at the boundaries of martensite plates were observed in the tempered martensite specimens. Dispersed carbide particles were present and were very similar in appearance in both types of micro-

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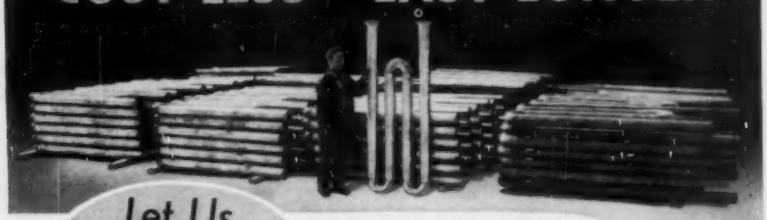

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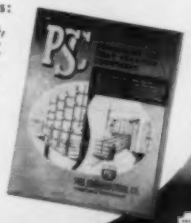

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Torsional Strength . . .

structure – tempered martensite and bainite.

The presence of the carbide films in one structure and their absence in the other leads to the suggestion that they are associated with the differences in mechanical behavior, particularly the erratic torsion test behavior of the high-hardness, tempered martensite specimens. It is recognized that residual quenching stresses may be important too, but long tempering times were expected to decrease their effect, and no such decrease was found for tempering times of 24 hr. or even 200 hr. The authors do not consider the possibility that the ferrite phase may be changing in properties during the tempering process, and that this too may be important in accounting for the mechanical properties.

The extraction replica technique, in which particles of the carbide phase are etched loose from their surroundings and then removed with a parlodion replica, was used to isolate the carbides. Electron diffraction identified them as the Hägg percarbide, Fe_2C, and cementite, Fe_3C. Cementite tended to predominate at higher tempering or isothermal transformation temperatures and was the only carbide identified in a specimen tempered at 600° F. In a specimen quenched and tempered 6½ hr. at 450° F., only Fe_2C was found.

DAVID A. THOMAS

Morphology of Leaded Steels

Digest of "Some Aspects of the Morphology and Chemistry of Lead in Leaded High-Sulphur Steels", by J. W. Thurman, E. J. Paliwoda and E. J. Duwell, Preprint No. 50, 1957.

IT HAS BEEN known for some 20 years that the machinability of steels may be significantly improved by the addition of small amounts of lead. This enhanced machinability is thought to be the result of internal lubrication which reduces friction at the tool-chip interface. Since the improvement is dependent on the dispersion of lead and on its mode

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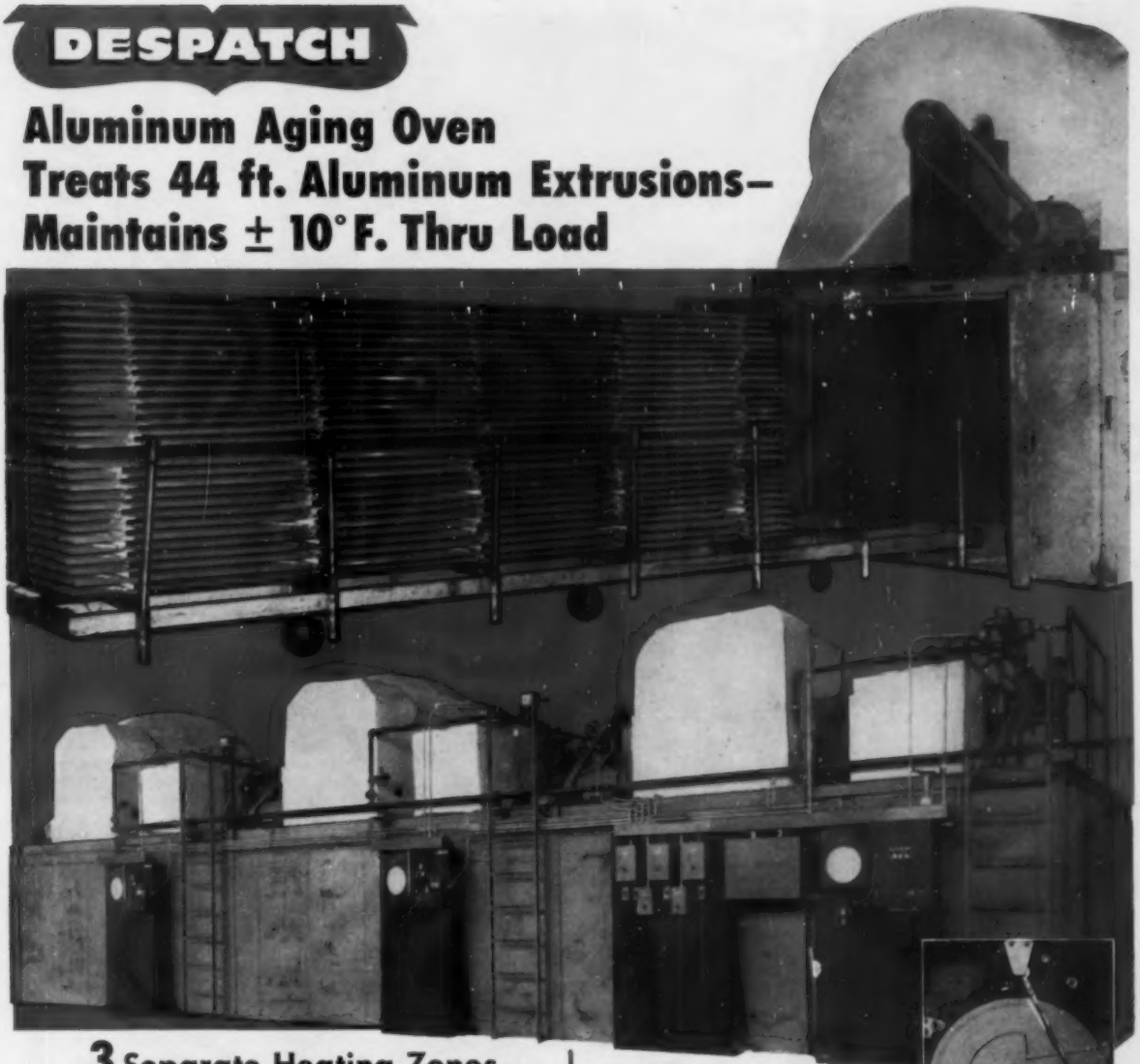

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A maximum charge of 6000 lbs. of aluminum extrusions is aged to specifications in this huge work area. Production reports are excellent, according to executives of Quality Aluminum Products Company of Coldwater, Michigan.

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This M. H. record of heat control illustrates the economy of time in aging aluminum extrusions in the Despatch Furnace. Your attention is called to the rate of recovery after a new charge is inserted. Also note the duration of aging periods. Quality Aluminum and Strong Engineering Inc. of Dearborn, Michigan, who sold and supervised this installation report impressive production economies are possible with this furnace.

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Leaded Steels . . .

of occurrence, methods for the study of its morphology are of importance.

Lead distribution has been determined in various ways, including exudation or sweat tests, printing methods and standard metallographic procedures, but none of these tests are altogether satisfactory. These methods, therefore, were supplemented by microradiography. An experimental commercial ingot of type "A" steel, both in the as-cast condition and after various reductions by hot rolling, was examined.

Foils used for the microradiographic work were 0.0035 in. thick. With the use of Kodak 649-O spectroscopic plates, processed in D-19 developer, magnifications in excess of 100 × could be obtained without undue graininess.

Comparison of microradiographs prepared with Co Kα and Cr Kα radiation, gives positive identification of manganese sulphide inclusions. Lead appears nearly white using either of these radiations but cobalt gives better detail.

The experimental ingot of Grade "A" steel analyzed 0.08% C, 0.98 Mn, 0.046 P, 0.300 S, and 0.17% Pb.

The ingot weighed 10,400 lb. and was poured into a 24 × 24-in. big-end-down mold with hot top. Lead (6.1 lb. per ton) was added to the mold in the usual way as 99.8% lead shot, finer than 20 mesh.

Foils for the microradiographic work were taken from the as-cast ingot representing top-to-bottom and surface-to-center locations. A surface immediately adjacent to the foil was prepared for metallographic examination.

Those portions of the ingot which cool rapidly (near surface and extreme bottom) showed extremely fine inclusions. The inclusions delineated a structure by having become entrapped in interdendritic fillings. As the interior of the ingot is approached the inclusions become larger and the crystallites which they outline are likewise larger and equi-axed. The lead constituent is confined to the same areas as the manganese sulphide. For the most part the lead particles are globular. They appear to be in physical contact with the sulphide, although occasional ones exist independently.

(*Continued on p.* 248)

STRAITS TIN REPORT

MALAYAN TIN BUREAU

New developments in the production, marketing and uses of tin

A number of new tin-zirconium alloys developed for use in the constructional elements of nuclear power plants have been patented by the U.S. Atomic Energy Commission. These alloys, containing from 1.8% to 4.5% tin and between 0.3% and 3.3% molybdenum, are said to have high tensile strength at elevated temperatures and excellent corrosion resistance.

★ ★ ★

A new group of alloys containing titanium, copper, aluminum and tin are said to react to heat treatment very much like steel. They are strong and ductile at temperatures up to 1000°F. and should have important applications in a variety of industries.

★★★★★★★★★★★★★★★★★★★★★★★★★★
★ ★
★ August 31 was Merdeka (Independence) Day in the Federation ★
★ of Malaya. It then became a new ★
★ self-governing nation in the British Commonwealth. The Chief ★
★ Minister, Tengku Abdul Rahman, who proclaimed the Federation's independence, had previously declared that a primary ★
★ concern of the Government is the ★
★ well-being of the tin-mining ★
★ industry. ★
★ ★
★★★★★★★★★★★★★★★★★★★★★★★★★★

Tin plating large engineering components—a problem for years—for the first time now has a commercially practical solution. "Dalic" plating brings the anode and the electrolyte to the workpiece, instead of vice versa. There are further advantages. The tin film deposited is finer grained. Deposition is both speedy and controllable to precise time limits.

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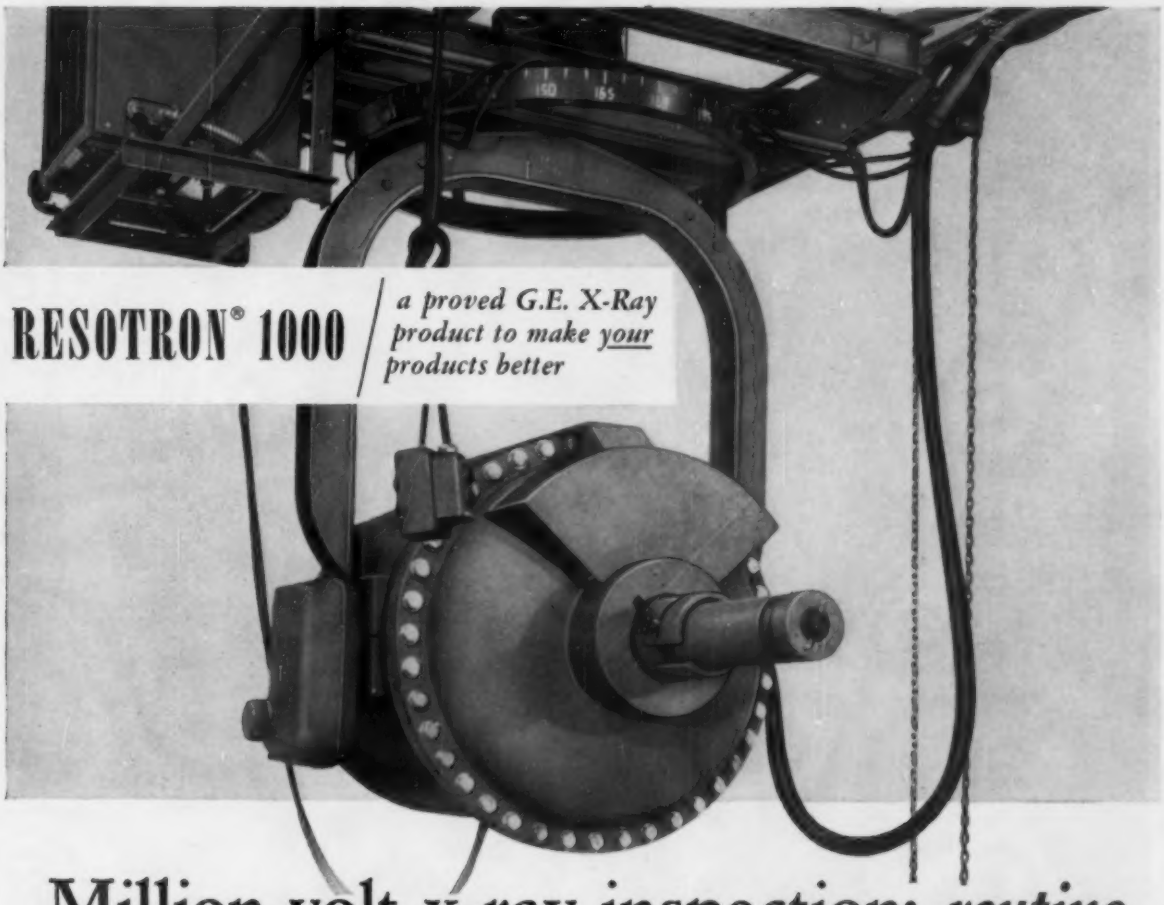
Continued experiments in bonding aluminum-tin bearing alloys to steel have brought greater improvements. By hard rolling the aluminum-tin so that its hardness is close to that of soft mild steel, the alloy can be rolled directly onto steel without aluminizing the steel first. This cuts out several manufacturing steps, with resultant savings.

Ask us to send you TIN NEWS, a monthly letter. It will keep you posted on tin supply, prices, new uses and applications.

The Malayan Tin Bureau

Dept. 25K, 1028 Connecticut Ave., Washington 6, D.C.



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Leaded Steels . . .

Within the interdendritic regions the distribution appears to be quite random. If the lead and sulphur contents are plotted over areas of interest in the ingot the two plots are almost exactly parallel. Considerable effort was expended to detect the presence of lead compounds by means of X-ray and electron diffraction. Only lead and manganese sulphide have been found so far and it seems safe to conclude that the lead present is largely, if not entirely, elemental lead. This implies that lead and manganese sulphide, although segregating by different mechanisms, are forced into the same areas as a result of the fact that both are trapped in the last metal to solidify in interdendritic spaces.

In general, the distribution of lead and the size of lead particles are a function of the time required for solidification in relation to the settling rate of lead particles.

Bars $3\frac{1}{2} \times 4$ in. were cut from ingot locations represented by the micrographs and were hot rolled. Microradiographic foils and metallographic samples were taken after 50, 75, 90 and 98% reductions. These samples show that as rolling proceeds the manganese sulphide inclusions gradually assume the lenticular shape which is characteristic of hot rolled high-sulphur steels. As the rolling progresses the position of the lead particles is changed and eventually they assume the form of sheaths at the ends of the elongated sulphide inclusions. This condition is typical of leaded high-sulphur steels. The effect appears to be mechanical. At steel rolling temperatures the lead is molten and the liquid metal in contact with the nonmetallic inclusions is forced to each end of the less plastic sulphide by a sort of extrusion process.

Occasionally, a sulphide inclusion completely enveloped with lead is observed. Apparently this is caused by variation in the relative amounts of lead and sulphide present as one inclusion. There is an interrelationship between the masses of the inclusion constituents during solifica-

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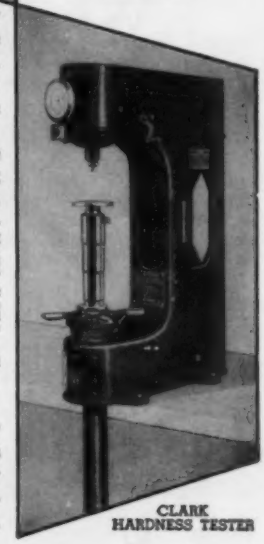

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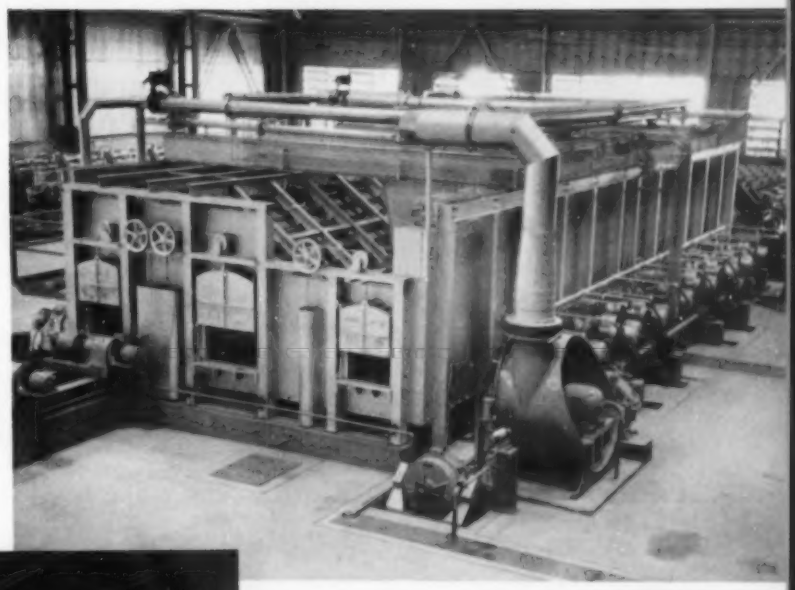
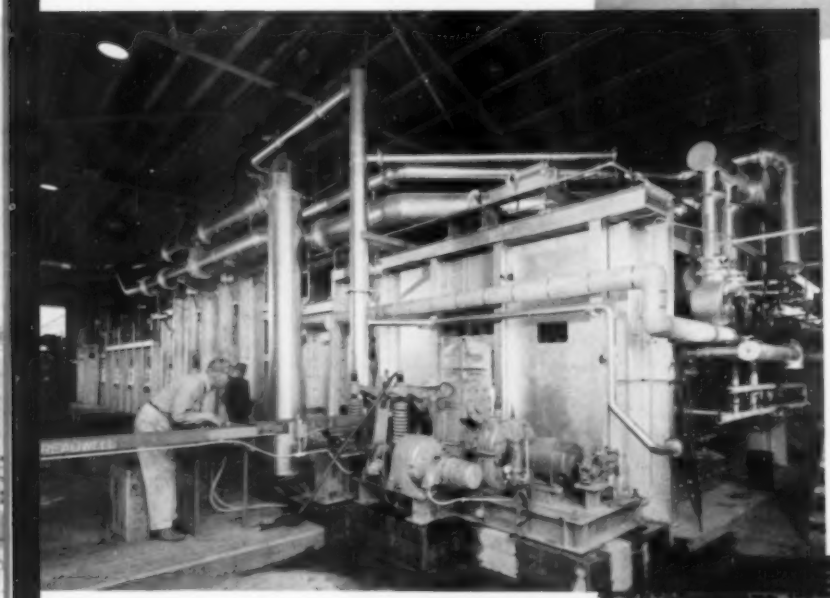


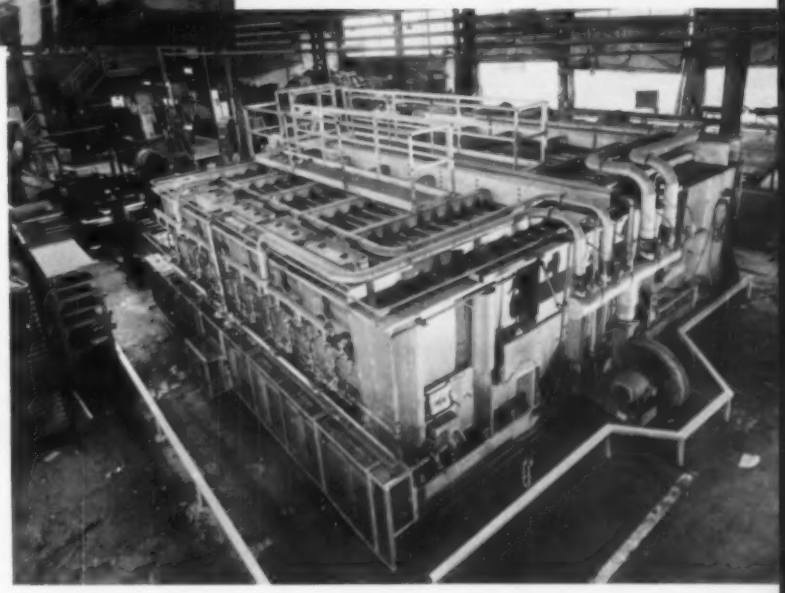
NORMALIZING FURNACE

This unit which was expressly designed and built for a manufacturer of seamless tubing, pipe and casing employs the use of a pusher type chain conveying the stock through the furnace at a capacity of 30 tons per hour.



REHEAT FURNACE

The 85 foot long multiple fired reheat furnace pictured to the left was built for the heating of ingots in a large west coast merchant mill operation. F & D has successfully designed and built many such installations throughout the world.



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3 phase—60 cycle—3400 rpm

Model	HP	Voltage	Weight
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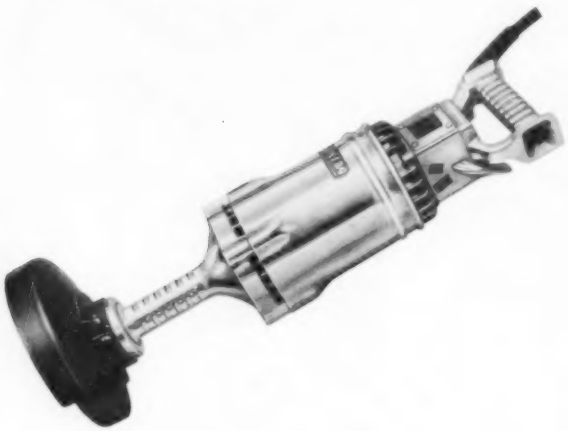
2324	1½	240	22 lbs
2424	2	240	26 lbs



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3 phase—60 cycle—3400 rpm

Model	HP	Voltage	Weight
3224	1	240	22 lbs
3324	1½	240	26 lbs
3434	2	240	30 lbs

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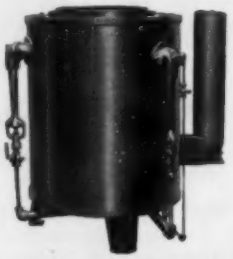

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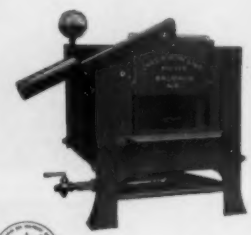

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Leaded Steels . . .

tion and subsequent hot working. In general, sulphide inclusions which are severely elongated and broken up during rolling exhibit fine "tails". Conversely, oval type sulphides retain relatively massive lead particles as sheaths.

In the as-cast ingot, there are occasional lead particles which are not associated with sulphide inclusions. During hot working these particles are severely elongated and appear ultimately as fine stringers of lead.

Microradiography is a useful tool for investigating the morphology of leaded steels, especially when used in combination with standard metallographic methods.

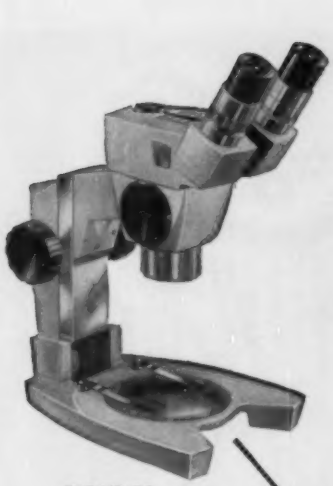
D. J. GIRARDI

Residual Stresses in Carburized Cases

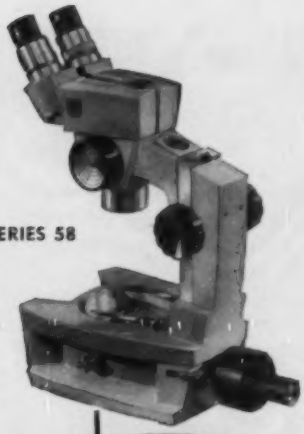
Digest of "The Distribution of Residual Stresses in Carburized Cases and Their Origin," by D. P. Koistinen, ⊕ Preprint No. 31, 1957.

X-RAY diffraction techniques are used to measure the stress distribution and retained austenite in carburized cases of S.A.E. 8620, 1118, 1018 and 5140 steels. The data support the theory that the origin of the compressive stress in the case lies in the sequence in which transformation of austenite occurs in the case and in the core. The magnitude of the compressive stress in the case is governed by the extent of austenite transformation to martensite.

Specimens in this study were gas carburized to a depth of about 0.045 to 0.050 in., quenched from the carburizing temperature in oil and tempered at 300° F. for ½ hr. Specimens studied were 0.250 in. thick, with both length and width of about 1.5 in. S.A.E. 8620 specimens were 0.500 in. thick. Measurements of residual stress and phase composition were made on the surface after electropolishing to prescribed depths. Precision X-ray techniques were used in which reproducibility and accuracy were satisfactory. Carbon contents were determined by chemical analysis of chips machined from the surface of simultaneously treated



SERIES 56



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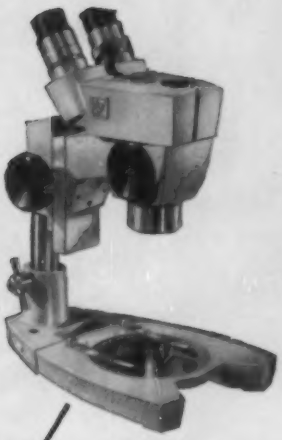

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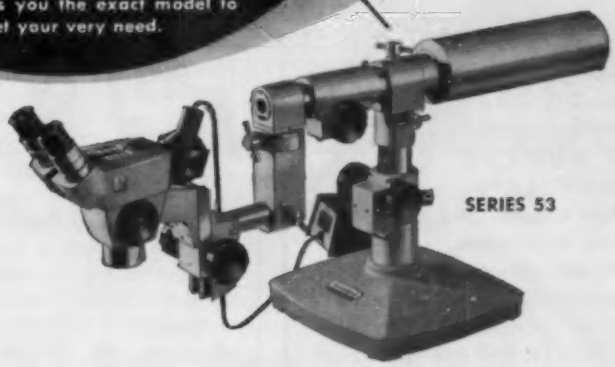

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Residual Stresses . . .

specimens. Decarburization of the surface up to about 0.002 in. occurred during quenching.

For the 8620 steel, maximum compressive stresses occurred at a depth of 0.030 to 0.035 in. (approximately 60% of the total case depth) at a carbon content of approximately 0.5%. Martensite start temperatures were calculated from the amount of retained austenite as a function of case depth. Combining this information with calculated cooling curves indicated that the transformation of austenite would occur in the sequence necessary to generate the compressive stresses observed. Other grades of steel studied showed similar correlations, with the magnitude of the compressive stress being determined by the amount of retained austenite.

The general conclusions reported by the author were as follows:

1. The magnitude and distribution of the compressive stress at every depth in a carburized case is determined by the extent of the transformation to martensite and the sequence in which these transformations occur.

2. Maximum compression occurs at 50 to 60% of the total case depth. In low-carbon core samples studied, this corresponds very closely to the point at which the carbon content drops below 0.5%.

3. The reversal in the sign of the residual stress from compression in the case to tension in the core occurs at or very near the boundary between case and core.

4. Proceeding outward through the case from the case-core boundary to the point of maximum compression, the stress becomes more compressive due to sequence of the transformations to isothermal transformation products or to martensite.

5. Proceeding outward through the case from the point of maximum compression to the surface, the magnitude of the compressive stress decreases as the amount of martensite is restricted by incomplete transformation of the austenite.

6. On some carburized specimens thin surface films may occur in which there are wide variations in phase compositions and correspondingly wide variation in residual stress.

D. J. CARNEY

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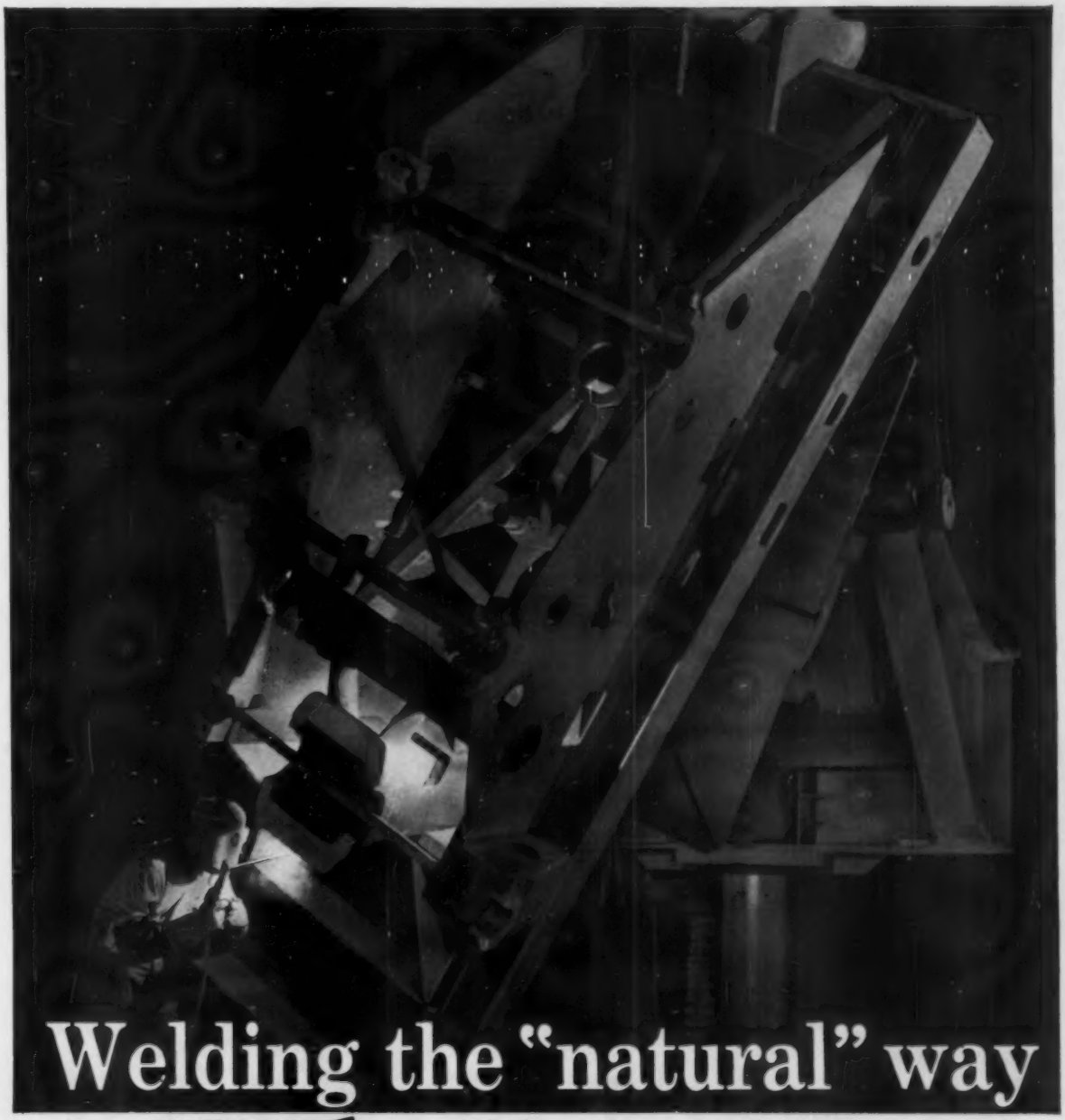

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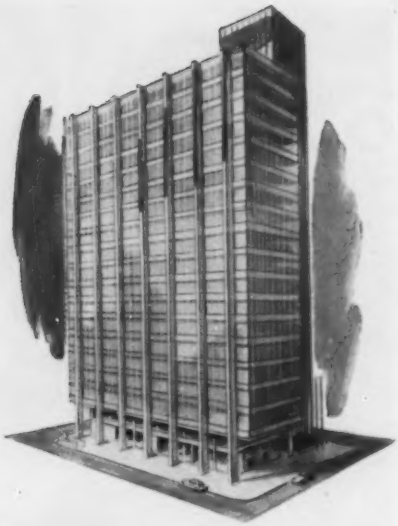

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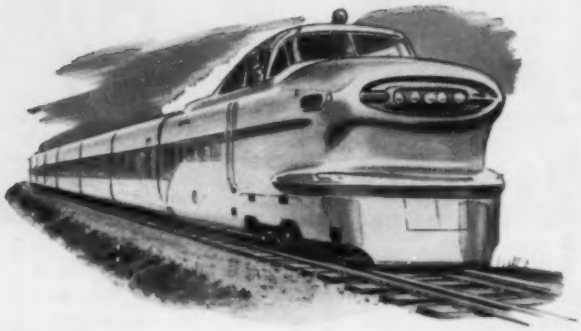

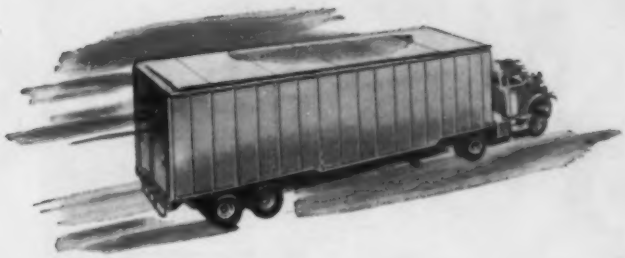

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Autoradiographic Study of Self-Diffusion in Nickel

Digest of "Grain Boundary Self-diffusion of Nickel," by W. R. Upthegrove and J. M. Sinnott, ⊖ Preprint No. 52, 1957.

THE EFFECT of the angle of misfit between nickel crystals on the rate of diffusion of radioactive nickel along grain boundaries in the temperature range 700 to 1100° C. (1290 to 2010° F.) has been determined by autoradiography.

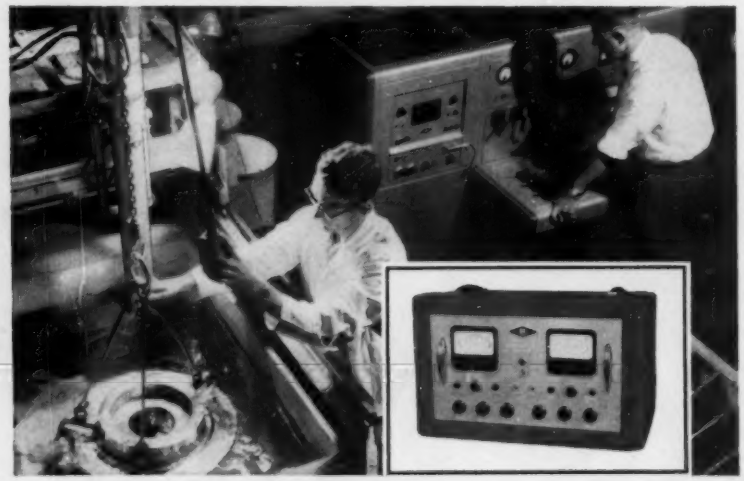
Bicrystals with simple symmetrical tilt boundaries were produced by use of single crystal seeds. These were placed in rotational relationship to one another around a common [100] axis during controlled cooling of melted electrolytic nickel. The angle of rotation was the grain boundary angle or the misfit angle. Diffusion specimens were prepared by sectioning the bicrystals perpendicular to the common [100] axis, and these sections were then etched and annealed. They were subsequently polished metallographically and chemically to produce flat strain-free surfaces. A layer of highly radioactive nickel-63 about 1 μ thick was plated over the grain boundary of each specimen, which was then sealed in a Vycor capsule with a tungsten or tantalum getter in a dried argon atmosphere.

Depth of penetration of the radioactive nickel along grain boundaries was measured by using the autoradiographic permeable-base stripping film technique. Each specimen was examined microscopically through the film. The distance was measured from the surface plated with radioactive nickel to the point where the activated emulsion along the grain boundary ended.

Penetration of radioactive nickel along grain boundaries increases with the grain-boundary angle and reaches a maximum at 45° – the maximum angular misfit. The rate of grain-boundary diffusion is apparently greater than the rate of lattice diffusion for all angles of misfit. The ratio of the former to the latter varies from 10^3 to 10^7 for boundary angles from 5 to 80° over the temperature range 700 to 1100° C. (1290 to 2010° F.). This ratio increases with increasing angular misfit and decreasing diffusion temperature.

In the temperature range studied a plot of the log of the calculated grain-boundary diffusion constants versus the reciprocal of absolute diffusion temperatures produced linear curves for boundary angles of misfit between 30 and 60°. At other angles the data showed deviations from straight-line relationships, particularly at high temperatures. These departures probably indicate that the formula used for the calculations is not precise under conditions of high temperature and low angular misfit.

The activation energy for diffusion in grain boundaries with angles of misfit between 20 and 70° is essentially constant at 26.0 ± 1.5 kg-cal. per g-mol., which is about twice the value previously reported. At lower angles the grain-boundary activation energy increases rapidly to the lattice self-diffusion activation energy of 65.9 kg-cal. per g-mol. at 0° angle. The following expression was ob-



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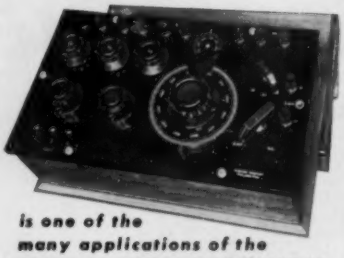

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Diffusion of Nickel . . .

tained for the lattice self-diffusion coefficient, D_L, as a function of the absolute diffusion temperature, T:

$$D_L = 0.48\ (-65{,}900/RT)$$

sq. cm per sec.

Agreement between the lattice coefficients obtained in these experiments and those recently reported by other investigators is very good. However, the results of this investigation did not support a recently proposed theory that the coefficient for self-diffusion along single grain-boundary dislocation pipes is independent of the boundary angle of misfit. R. F. STOOPS

Hydrogen Pickup in Pickling of Titanium

Digest of "Factors Affecting the Absorption and Distribution of Hydrogen in Titanium During Acid Pickling", by C. R. McKinsey, M. Stern and R. A. Perkins, ⊕ Preprint No. 38, 1957.

HYDROGEN PICKUP and distribution in titanium and its alloys during acid pickling are controlled by a variety of interrelated environmental and metallurgical factors. Corrosion of the metal surface by the acid results in the formation of hydrogen atoms which constitute an effective hydrogen pressure, and this pressure is the driving force for diffusion into the metal. Any factor which alters the rate of reduction of hydrogen, such as changes in acid concentration or addition of passivating agents, will affect hydrogen pickup. For instance, when titanium sponge was corroded in both 1% HCl and 5% HCl for the same length of time, the hydrogen pickup for the specimen in the 5% HCl was 3.7 times that in the 1% HCl. Also, when ferric ion, a passivating agent for titanium, was added to 1% HCl, the hydrogen pickup in this solution was reduced by a factor of 100.

In predominantly alpha alloys, total hydrogen pickup is related directly to the amount and distribution of the beta phase, and the hydrogen absorbed is concentrated as titanium hydride in a thin surface layer. The presence of beta phase results in deeper penetration of hydride as compared with that obtained

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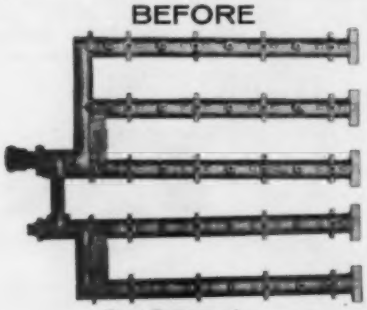

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Machining	2.76
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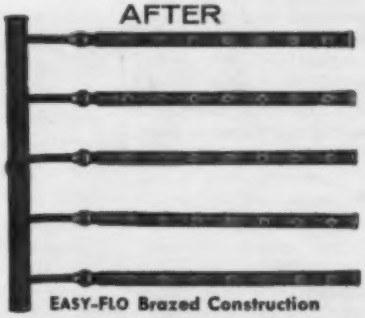

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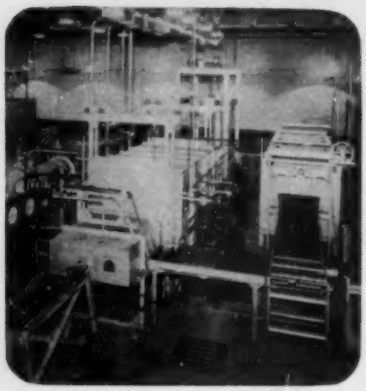

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in all-alpha structures. A network of beta permits much deeper penetration of hydride than does a random dispersion. The depth of penetration in acicular (martensitic) alpha also is greater than in equiaxed alpha, indicating the presence of retained beta in the structure.

Beta-rich alloys are much more susceptible to hydrogen pickup than are the alpha-rich alloys. However, the beta alloys do not form hydride layers. In an 8% Mn alloy containing 75% beta phase and 12,000 parts per million of hydrogen, no hydride was found in the microstructure. This amount of hydrogen is far in excess of that predicted by McQuillan's thermodynamic extrapolation of the beta/beta + hydride phase boundary in the titanium-hydrogen binary system. However, the presence of manganese would be expected to modify this boundary. Also, as proposed by McQuillan, beta may be supersaturated due to difficulty of nucleating hydride in a body-centered cubic matrix. Large amounts of hydrogen in beta-rich alloys create internal stresses which may lead to intergranular cracking and formation of acicular alpha.

The stability of the hydride surface layers formed in predominantly alpha alloys was studied by heating for different lengths of time at temperatures up to 400° C. (750° F.). The hydride layer was unchanged after several months at room temperature or 1 hr. at 100° C. (212° F.). After 24 hr. at 100° C. (212° F.), some dissociation and diffusion had occurred. A similar change was noted after 1 hr. at 200° C. (390° F.). After 24 hr. at 300° C. (570° F.) or 1 hr. at 400° C. (750° F.), the hydride layer had completely disappeared.

The fact that a hydride layer forms during pickling of alpha-rich alloys may be important since it probably leads to mechanical behavior different from that produced by uniform hydrogen content. The hydride layer also makes a significant contribution to the total hydrogen content, especially of sheet materials. Hydrogen analysis of pickled titanium sheet may be in error if the original surface is not included in the sample analyzed.

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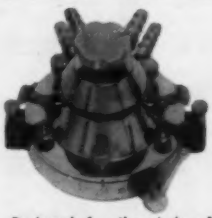

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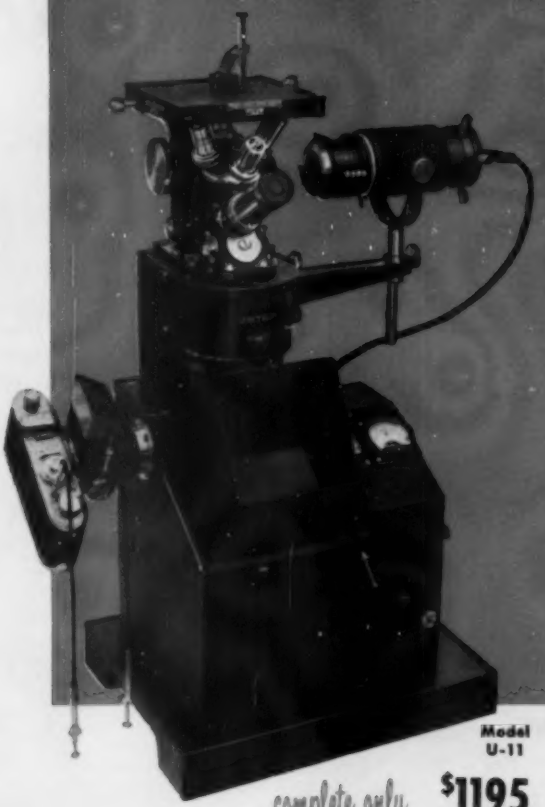

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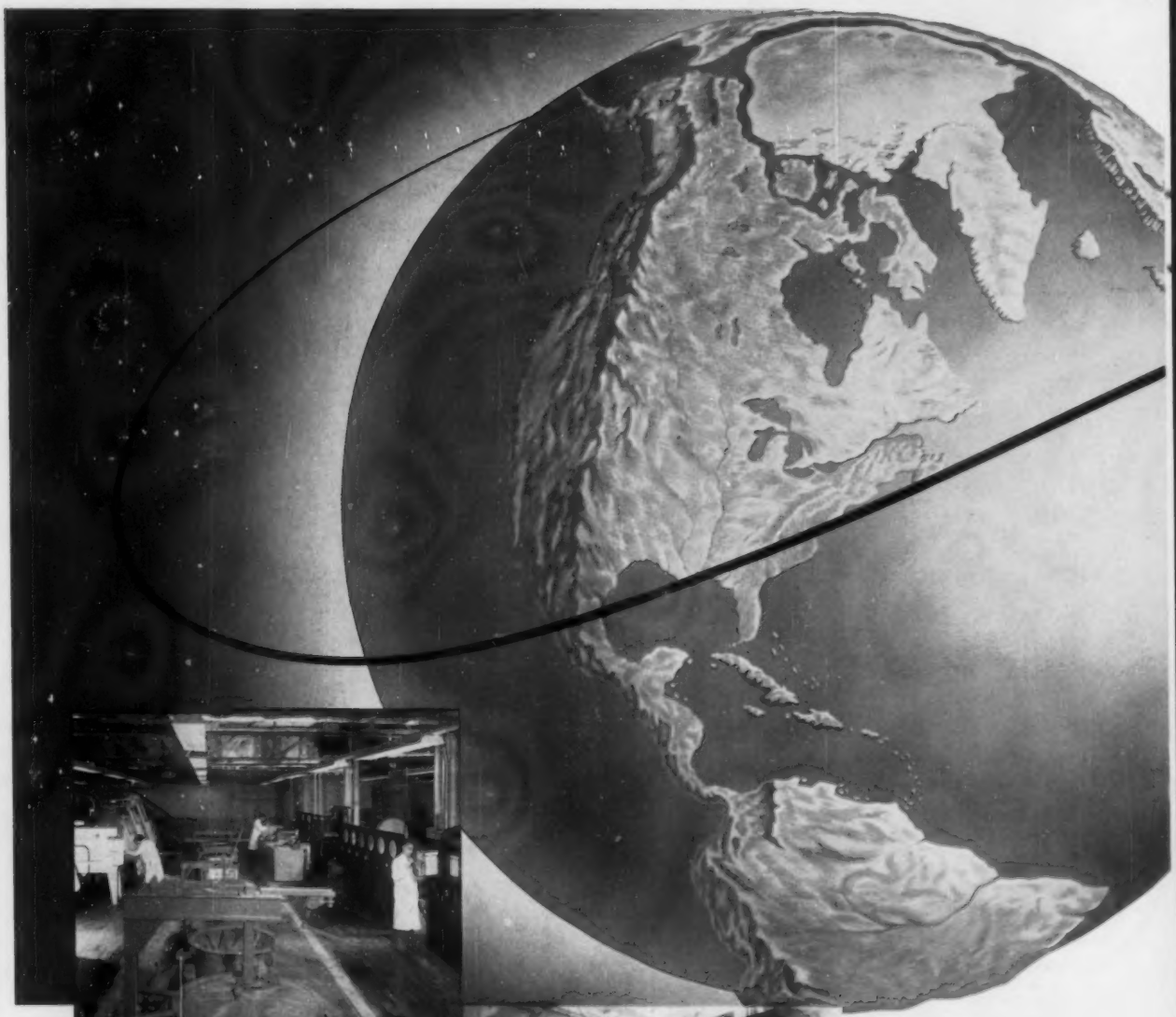

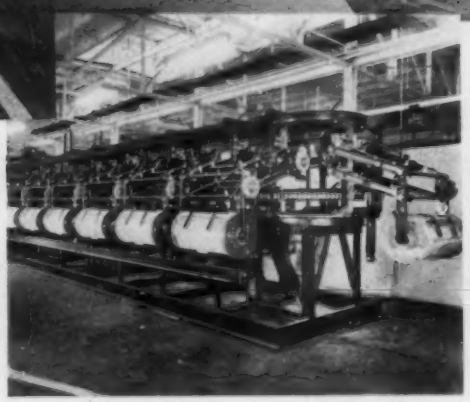

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Grain Boundary Movements in Bicrystals

Digest of "Unpredicted Grain-Boundary Movement in Bicrystalline Aluminum", by R. B. Pond and E. Harrison, ⊕ Preprint No. 43, 1957.

STUDIES of the deformation behavior of bicrystalline test specimens having controlled orientations and grain-boundary positions are supplying some of the information needed to bridge the gap in existing knowledge of deformation between the well-established mechanisms applicable to single crystals and the more complex actions of polycrystalline aggregates. These investigations provide additional understanding of the nature of grain boundaries and determine whether a simple dislocation model is adequate to account for boundary behavior or whether a more complex structure of atoms and vacancies is indicated.

In most of the earlier research with bicrystals the specimens were prepared in such a manner that the grain boundaries extended along the longitudinal axis of the specimens and therefore parallel to the direction of the applied stress. The authors point out that in such specimens translations at the boundary are restrained by the grips when applying tension, and their objective was to prepare bicrystal specimens having the grain boundaries located and oriented to avoid the restraining influence of grips.

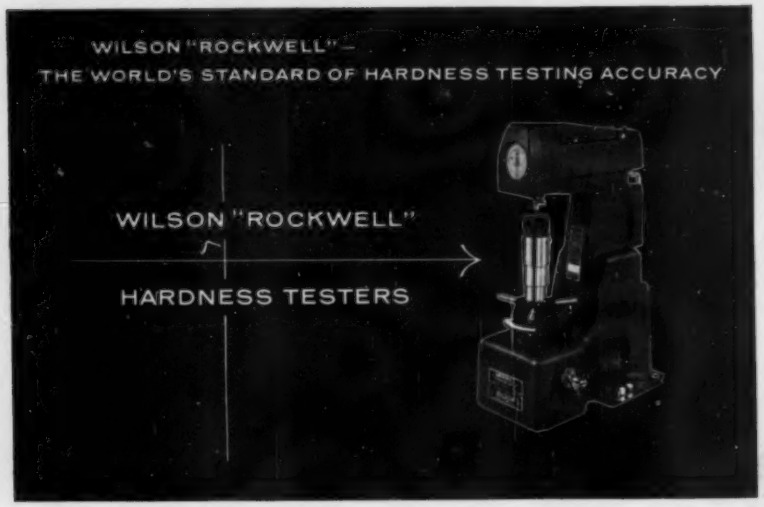
The ingenious method devised to prepare such specimens warrants description in some detail. The bicrystalline specimen was produced from a single crystal which had been grown by a modified Bridgman technique from high-purity aluminum (99.99+%). A short zone through the cross section of the single crystal near the midpoint of its length was melted momentarily by means of a small oxy-acetylene torch. While this restricted zone was molten one end of the specimen was rotated relative to the other about the specimen axis and displaced slightly toward the other end without rupturing the fluid coupling between the two ends. By selecting the original crystal orientation and controlling the amount of rotation the authors were able to develop either tilt or twist-type boundaries.

The tests described all were conducted on specimens having the single grain boundary located perpendicular to the applied stress. It was observed that these boundaries translated during deformation causing the specimen to assume a "V" shape. In tensile specimens the translation was away from the acute angle made by the intersection of the active slip planes in the two grains. In compression specimens, the translation was in the opposite direction. No bending of the slip planes was observed in the vicinity of the grain boundary in either case.

It was determined that the index of strain hardening and the stress level for a given strain in the advanced plastic region were lower for bicrystals having grain boundaries free to translate than for single crystals of the same parent orientation. Restraint of the grain-boundary translation would be necessary to produce strength in the bicrystal equal to that of the single crystal. In polycrystalline materials this restraint is, of course, supplied by the presence of additional grains having a diversity of orientations.

These new studies of grain-boundary movements should be helpful in developing a better understanding of creep and relaxation.

H. Y. HUNSICKER



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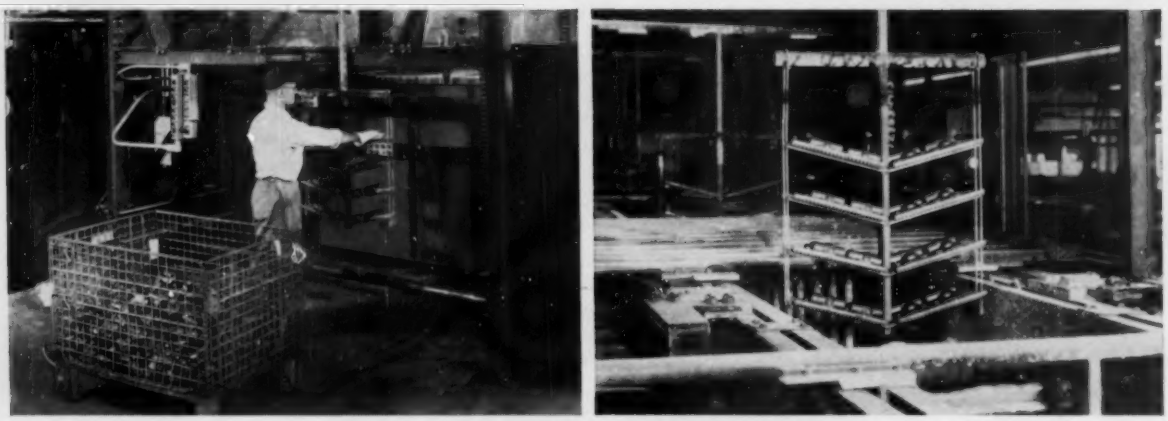

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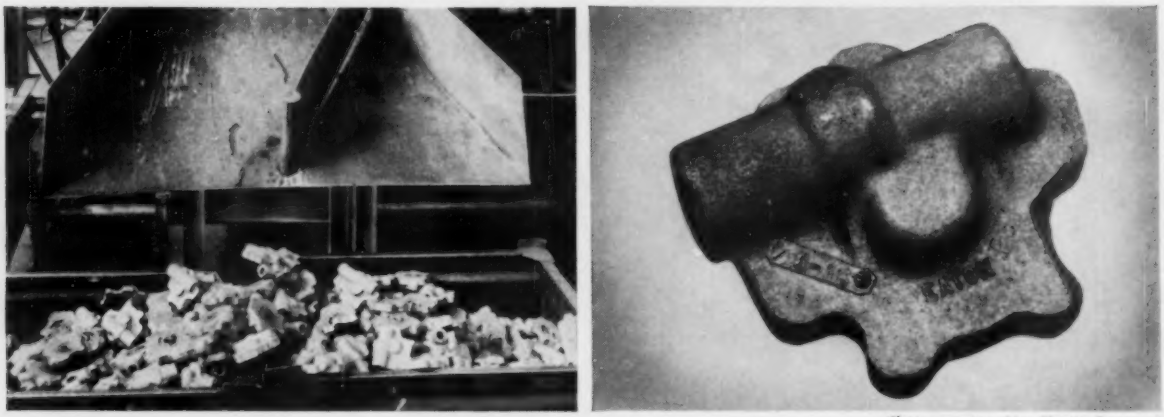

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Mechanical Properties of Ti-V Alloys Related to TTT Diagrams

Digest of "Mechanical Properties Correlated With Transformation Characteristics of Titanium-Vanadium Alloys", by E. L. Harmon, J. Kozol and A. R. Troiano, ⊜ Preprint No. 26, 1957.

MICROSTRUCTURAL changes in titanium-vanadium alloys resulting from a variation in alloy content and heat treatment exert a considerable influence on mechanical properties. In this investigation mechanical properties of alloys containing up to 24% vanadium are related to time-temperature-transformation diagrams.

Eight-pound ingots of one group of alloys containing 0, 2.5, 7.5, 12.5 and 15% vanadium were prepared by arc melting in inert atmosphere, and were rolled to ½-in. square bar. Similar ingots of alloys containing 5, 11, 20, and 24% vanadium were also prepared and rolled to ¾ in. square bar. Except for the unalloyed titanium all alloys were double melted to insure homogeneity. The 0, 2.5 and 7.5% vanadium alloys were rolled at temperatures in the alpha-beta field; the remaining alloys were rolled in the beta field.

Dilatometric and metallographic specimens were solution treated in argon atmosphere; other specimens were solution treated in vacuum (pressures below 5×10^{-4} mm. Hg). Aging and isothermal treatments up to 1020° F. were conducted in salt baths; above this temperature lead baths were employed. Isothermal transformation up to 1020° F. was investigated with a quenching dilatometer. Six seconds after quenching was the shortest time at which this reaction could be observed. Dilatometric study of isothermal transformation behavior was supplemented with metallographic examination.

Notched Charpy impact specimens were used to determine impact transition curves on all of the alloys solution treated at 1800° F. Transition curves for 11, 20 and 24% vanadium aged at 450° C. (840° F.) also were determined.

Mechanical properties were determined on both notched and un-

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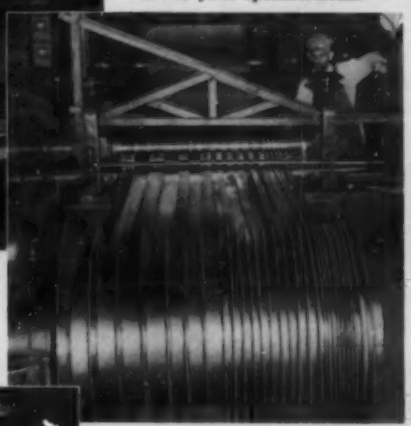

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notched specimens. The following conditions were investigated:

1. As-quenched strength (yield and ultimate tensile strengths) and ductility (reduction of area) as functions of vanadium content. All were solution treated for 2 hr. at 1800° F. and brine quenched.

2. Tensile strength and reduction in area on all alloys from 11 to 24% vanadium. All were aged to maximum obtainable combination of strength and ductility.

3. Tensile strength and reduction in area of a 15% vanadium alloy quenched from 1800° F. to various aging temperatures.

4. Tensile strength and reduction in area of a 20% vanadium alloy quenched from the beta region to 660° F.

5. Tensile strength and reduction in area of aged 7.5 and 12.5% vanadium alloys solution treated at temperatures from 1200 to 1330° F.

6. Tensile strength and reduction in area of a 15% vanadium alloy brine quenched from 1800° F. and aged for various times at 885° F.

Relative notch ductilities were determined for the two following conditions:

1. All alloys solution treated.

2. Alloys of 11, 20 and 24% vanadium solution treated versus solution treated and aged at 840° F. for various times.

Results of the investigations are summarized as follows:

1. As shown by TTT-diagrams, vanadium contents of 20 and 24% increased the time for alpha and omega to form, thus making it possible to quench past the omega "nose" on these alloys. Omega formation occurs at shorter times than for alpha (0.7 min. versus 2 min. on the 20% vanadium alloy and 9 min. versus 90 min. on the 24% vanadium alloy).

2. Alloys up to 7.5% vanadium consist essentially of alpha prime after quenching. The tensile strength increases continually with increases in vanadium content (45,000 to 135,000 psi.) accompanied by a marked decrease in ductility (from 85% to 30% reduction in area).

3. The quenched 11% vanadium alloy exhibited high ductility (75% reduction in area) with low ratio of yield to ultimate tensile strength (50,000 psi. yield to 105,000 psi. ultimate tensile strength).

4. Quenched 12.5 and 15% vanadium alloys exhibited low ductility (7% and 30% reduction in area) because of the presence of omega. Vanadium contents of 20 and 24% retarded this precipitation with subsequent beta retention and a high level of ductility (70 to 75% reduction in area), but reduced strength (110,000 psi. to 100,000 psi.).

5. Using the results of tensile tests as a basis for heat treatment, quenched 11, 20 and 24% vanadium alloys were aged to ultimate tensile strength of 150,000 psi. Notch sensitivity in notched tensile tests was unchanged for the 20% vanadium alloy but increased on the 11 and 24% alloys relative to the as-quenched condition. Impact energy levels were lowered for all three alloys, which of course had higher tensile strengths than the as-quenched material.

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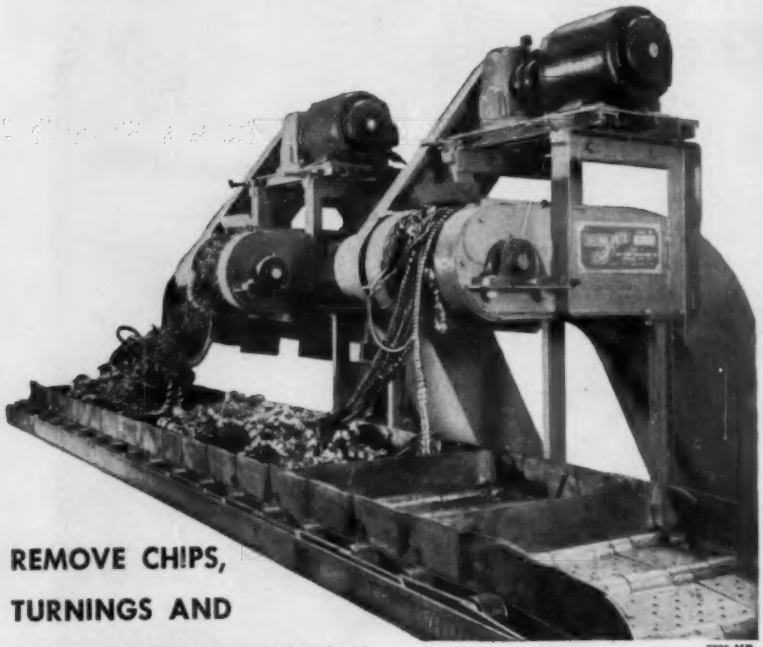

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Temperature-Time Effect on Tensile Properties of Aluminum

Digest of "Effects of Temperature-Time Histories on the Tensile Properties of Airframe Structural Aluminum Alloys", by R. E. Fortney and C. H. Avery, Preprint No. 23, 1957.

INVESTIGATION of the effect of temperature-time exposure on the yield and ultimate tensile strength of 2024-T 3 and 7075-T 6 clad aluminum sheet has resulted in data for determining tensile strengths in the estimated usage range for airframes. Temperatures ranged from room through 400° F. after complex sequences of exposure in the range from room temperature through 500° F. for times of 1 through 1000 hr. The test data were expanded to include all points within the ranges mentioned by application of normalization and generalization procedures to the yield and ultimate tensile strength data, using semi-empirical parameters based on the rate process theory. Statistical calculations determined the degree of conformity of test data and generalized equations. These equations are believed adequate for analyzing the effects of service exposure within the range from room temperature to 500° F. and 1 to 1000 hr. tensile strength of airframe alloys at room temperature up to 400° F.

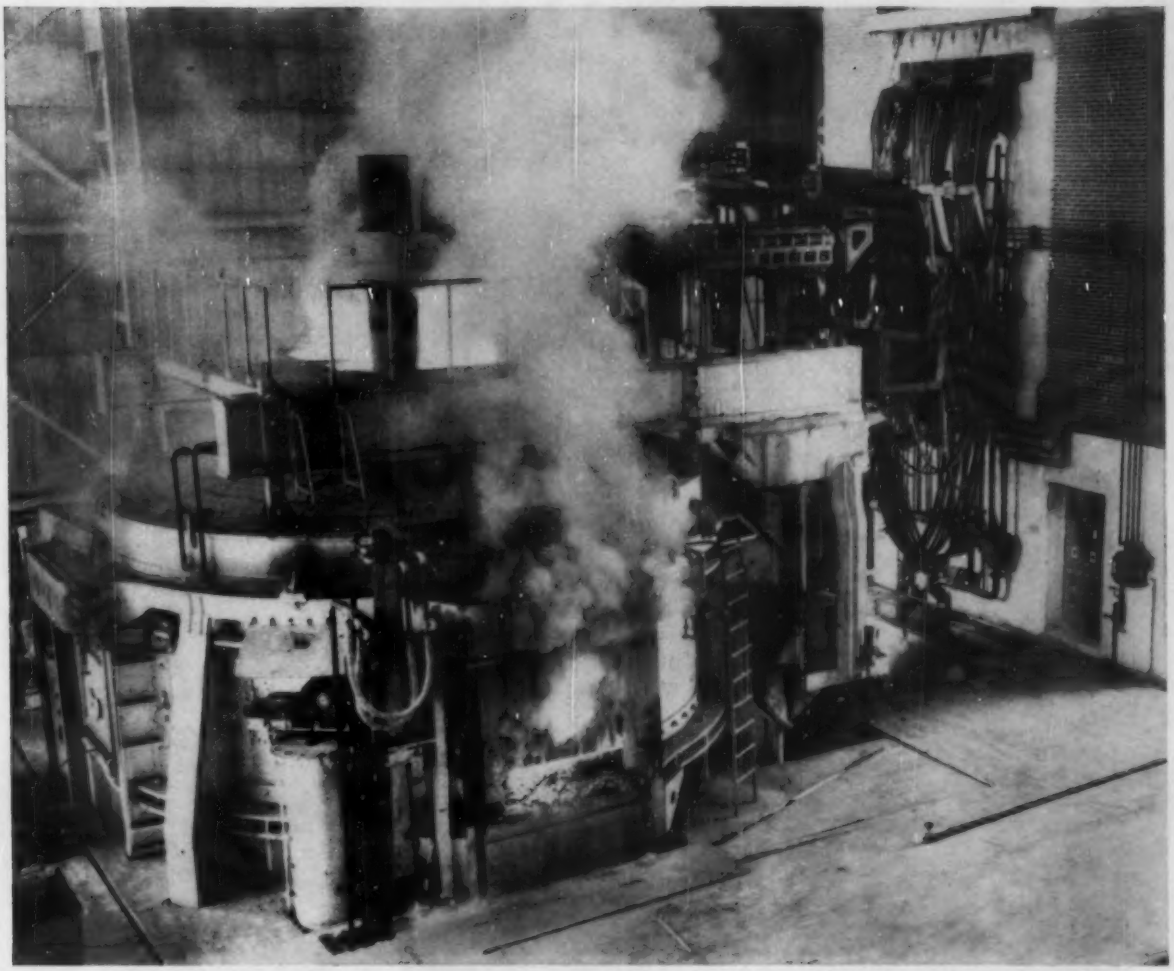
Both single and sequential exposures were utilized in obtaining the data. Tensile specimens of 0.064-in. 2024-T 3 and 7075-T 6 alclad sheet were cut with the axis of each specimen transverse to the rolling direction. Tensile strength properties were expressed in terms of "percent of room temperature properties" to minimize effect of inherent material variability.

The tests were carried out in conventional air furnaces. Various control measures taken were:

1. Temperature control of tensile specimens was maintained to ± 5.5° F. or less of the temperature listed for 0.1 and 1.0 hr. exposures.

2. Temperature control of tensile specimens was maintained to ± 8.0° F. or less for exposure periods longer than 1.0 hr.

3. Time at temperature was controlled to a maximum variation of



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Strength of Aluminum ...

1 min. for 100 to 1000-hr. exposures.

4. Time at temperature was controlled to a maximum variation of 20 sec. for 0.1 and 10-hr. exposures.

5. Triplicate tensile specimens were tested at each temperature.

Modified Larson-Miller parameter type curves resulted from the generalization of the test data for single exposures. These temperature-time parameters, plotted against nondimensional tensile strength, make it possible to predict the tensile yield or ultimate strength of either material at room temperature, 200, 300, and 400° F. after almost any normal, single, service exposure to which these materials will be subjected. This generalized data presentation greatly assists analysis of temperature-time exposures. However, the analysis of tensile test temperature is very restricted. Reducing the curves to a single curve will overcome this restriction. To do so the nondimensional tensile strength is replaced by a ratio of strength at test temperature after exposure to strength at test temperature with no exposure. Further qualifications empirically minimize the scatter of test results.

Four-step sequential exposures can be predicted by calculating an effective time-temperature parameter for the sequence of exposures. This is done by representing each individual exposure by times at a reference temperature; this is used to calculate exposure parameter (time-temperature) for the sequence. A comparison of the sequential data with the derived single exposure curve for nondimensional strengths shows close agreement. A statistical analysis indicates that over 95% of the sequential exposure data are within 10% of the nondimensional strengths of the single exposure curves.

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Influence of Tempered Martensite on Fatigue Properties of Steel

Digest of "The Effect of Per Cent Tempered Martensite on Endurance Limit", by F. Borik, R. D. Chapman and W. E. Jominy, ⊕ Preprint No. 16, 1957.

THE CORRELATION of microstructure with mechanical properties of steel continues to offer opportunities for investigation despite extensive past work in the field. This paper presents a systematic study of the influence of the martensite content of five steels on fatigue properties, particularly the endurance limit, after tempering all specimens to the same hardness.

Previous work has led to the widespread general conclusion that tempered martensite has superior mechanical properties compared to ferrite-bainite-pearlite structures at the same tensile strength. The question that remained unsatisfactorily answered was the effect of small amounts of nonmartensitic constituents on the fatigue properties of predominantly martensitic materials.

Accordingly, five low-alloy steels of similar carbon content – namely

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Tempered Martensite . .

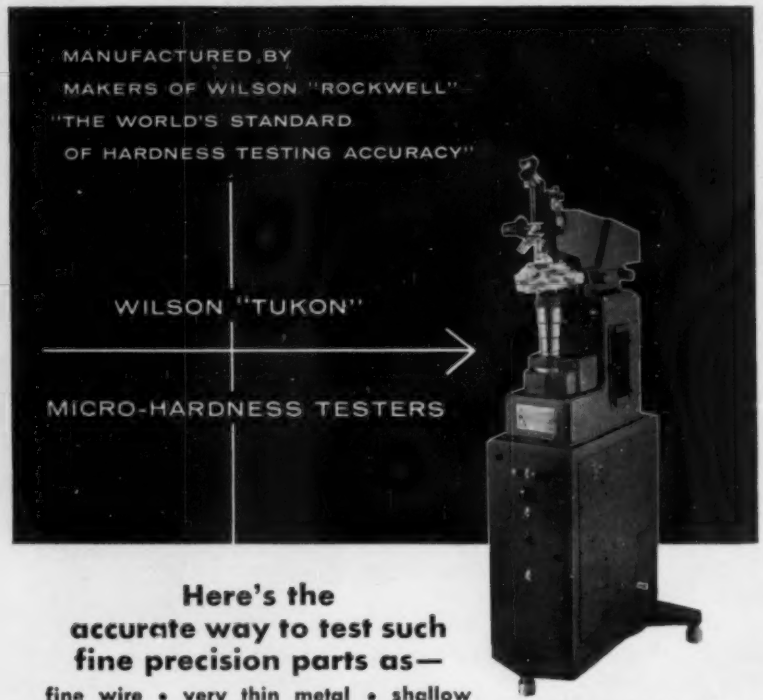
S.A.E. 1340, 4042, 4340, 5140, and 80 B 40 – were quenched at various rates to obtain varying percentages of martensite, ranging from 100% to 20%. An end quenched bar was used to determine the relationship between as-quenched hardness and per cent martensite for each steel, the per cent martensite being determined metallographically along the bar by four independent observers. The nature of the nonmartensitic products was not determined, but near the quenched end of the bar these products are probably bainite and ferrite.

Step-diameter bars were then quenched into six different mediums ranging in effectiveness from still water to still air. From these bars, suitable bar sizes and quenching mediums were chosen to obtain the desired martensite contents. Six bars for each series were heat treated in the predetermined way, and then they were tempered at successively higher temperatures until the desired hardness of Rockwell C-36 was attained. The required tempering temperatures were approximately 700 to 1000° F., and the hardness ranged from 33.0 to 39.0, but usually within 1 point of the desired value of C-36. Each series of 12 to 15 samples was accompanied by 3 check samples that were successively cut up and checked for hardness and microstructure after each heat treating step.

Fatigue specimens, with a minimum diameter of 0.250 in., were machined and carefully ground; then they were superfinished to a surface roughness specification of 0 to 2 micro-inches. The fatigue bars were tested in R. R. Moore fatigue testing machines (10,000-rpm. type) to fracture or to 100 million cycles. S-N curves were plotted to determine the endurance limits.

The results show that the endurance limit is highest (about 90,000 psi.) for those specimens that were fully martensitic before tempering. The presence of a few per cent of nonmartensitic structures produces a surprising drop in the endurance limit – down to 82,000 psi. at 85% tempered martensite. Below 85% martensite the endurance limit decreases slightly until it is about 76,000 psi. at 50% martensite. There is a certain amount of scatter when the data are plotted, and the data are thus represented by a band about 7000 psi. wide.

The endurance limit data for 100% martensite agree closely with the work of Garwood, Zurburg, and Erickson ("Correlation of Laboratory Tests and Service Performance", paper in "Interpretation of Tests and Correlation With Service", published by A.S.M., 1951, p. 1-77). For hardness values of Rockwell C-36, the endurance limits for several steels of 0.4 to 0.6% carbon content fall between 88,000 and 93,000 psi., which is very close to the values found in this investigation. The data do not correlate well with those of Hodge and Lankford ("Influence of Nonmartensitic Transformation Product on Mechanical Properties of Tempered Martensite", N.A.C.A., Technical Note 2862, December 1952) for S.A.E. 4340 steel with varying percentages of bainite, fer-



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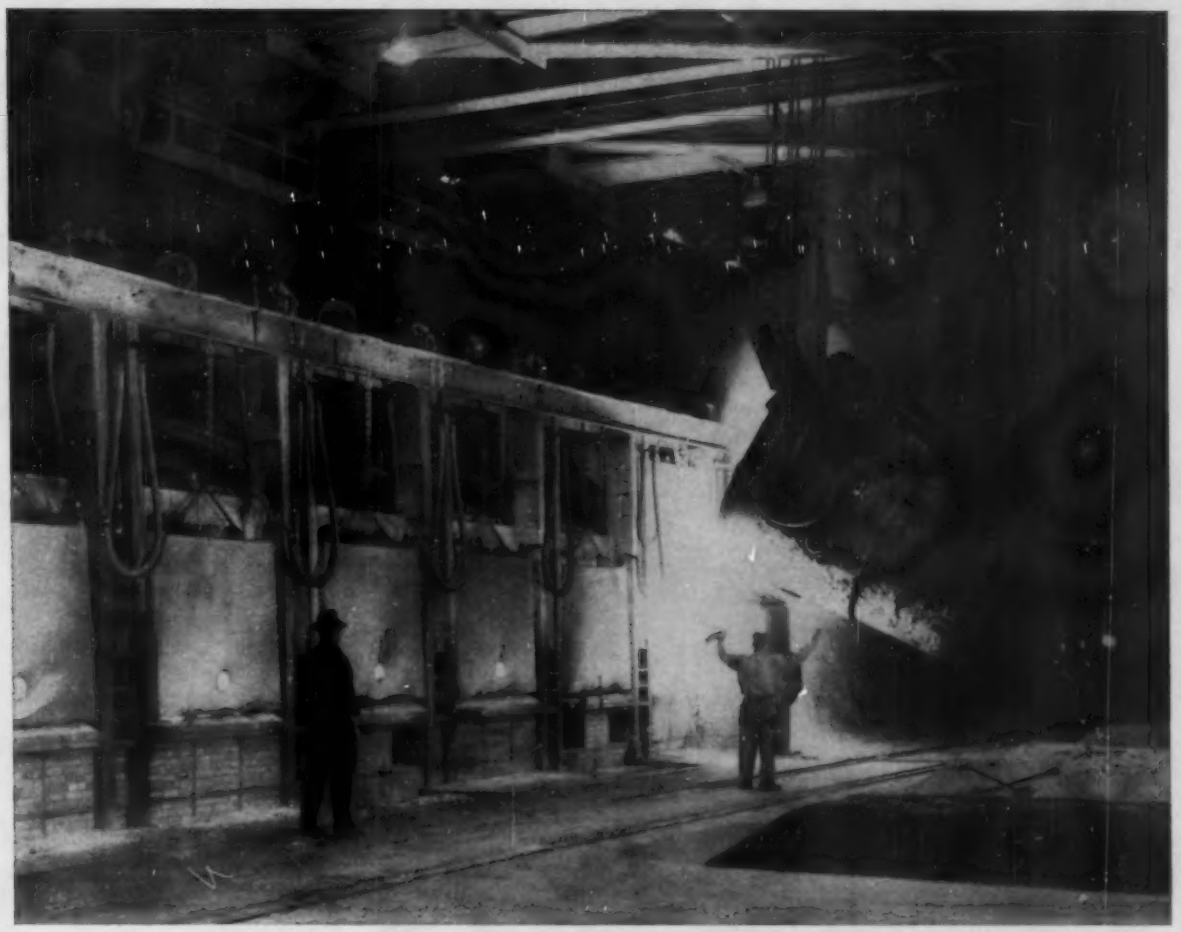

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57.8.3

Tempered Martensite . .

rite, and pearlite formed isothermally. Their endurance limit of 72,000 psi. seems low for their tempered hardness of Rockwell C-34.

Desirable additions to this investigation would be the study of more steels and more hardness ranges, and a more precise method for measuring the per cent martensite in the as-quenched condition.

Varying opinions exist on the amount of martensite required at various positions in quenched parts in order to obtain optimum properties. Some specifications require 90% martensite at ¾ radius, and others require only 80% or 50%. The data reported here indicate that a higher endurance limit would result at ¾ radius with the 90% requirement. Furthermore, the likelihood of obtaining 100% martensite at the surface is greater with the 90% specification. This is important where a part is subjected to fatigue loading because of the adverse effect of small amounts of nonmartensitic products on the endurance limit. If 100% martensite is obtained at the surface, there appears to be little difference between the 50% and 80% martensite requirement at the ¾ radius because the endurance limit is not sensitive to microstructure in this range.

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Etching Metals by Ionized Gas

Digest of "A Method for Etching of Metals By Gas Ion Bombardment", by J. B. Newkirk and W. G. Martin, ⓐ Preprint No. 8, 1957.

IN *Metal Progress*, June 1954, p. 108, Padden and Cain published a paper describing techniques for etching metallographic specimens with ionized gases. The present treatise describes modifications to the system which save time and provide better vacuum conditions.

Ion etching techniques are especially applicable to porous specimens or to samples whose surface properties may be altered or destroyed by heat generated in chemical reagent etching.

The apparatus, constructed of glass, is equipped with a 4000-volt power source, an electrode for ion generation, a field coil to concentrate the ion stream and a pedestal on which to position the specimen. Auxiliary equipment includes a vacuum pump, argon supply and krypton source.

A mechanically polished specimen is placed in the apparatus and the system evacuated and flushed with argon twice. Final evacuation, to a pressure level of 1μ, is followed by the introduction of enough krypton to bring the pressure up to 15μ. Power is turned on, and the ionized krypton etches the surface by bombardment.

Most specimens may be etched in less than 5 min., during which the maximum specimen temperature does not exceed 150° C. (300° F.).

The procedures are described, and examples of alloys which are difficult to etch by the more conventional wet methods are shown.

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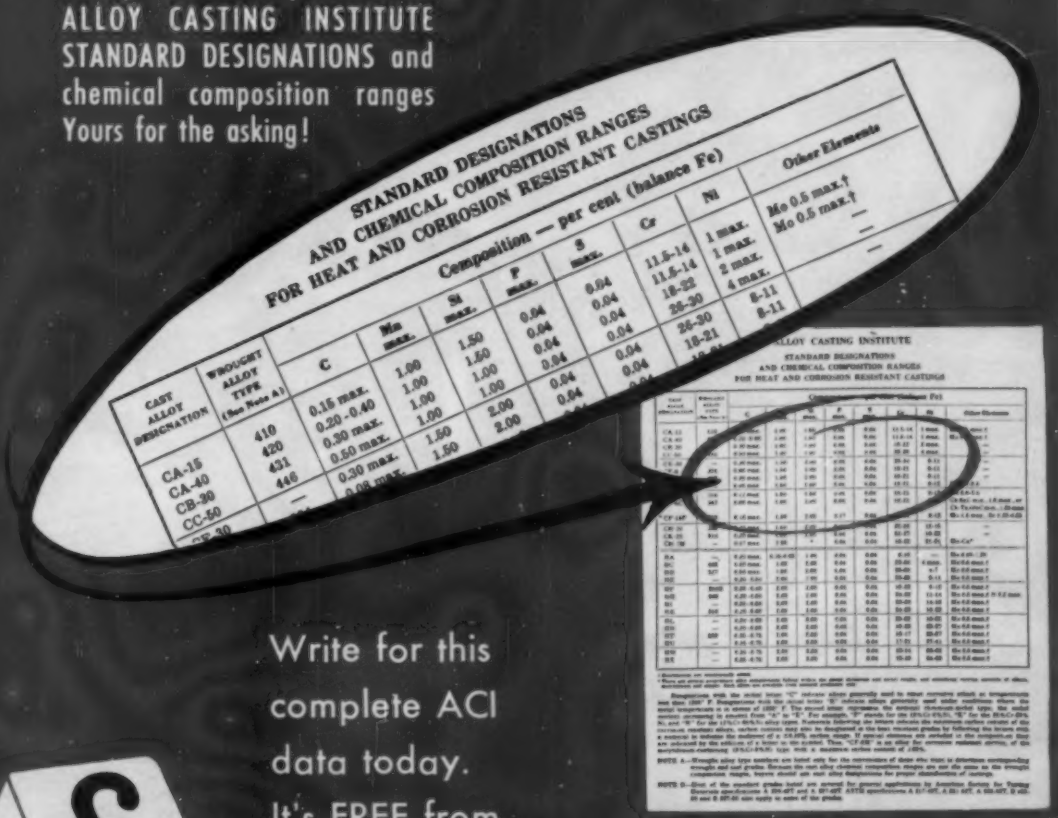
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		C	Mn max.	Si max.	P max.	S max.	Cr	Ni	Other Elements
CA-15	410	0.15 max.	1.00	1.50	0.04	0.04	11.5-14	1 max.	Mo 0.5 max.†
CA-40	420	0.20-0.40	1.00	1.50	0.04	0.04	11.5-14	1 max.	Mo 0.5 max.†
CB-30	431	0.30 max.	1.00	1.00	0.04	0.04	18-22	2 max.	—
CC-50	446	0.50 max.	1.00	1.00	0.04	0.04	25-30	4 max.	—
CE-30	—	0.30 max.	1.50	2.00	0.04	0.04	26-30	8-11	—
		0.08 max.	1.50	2.00	0.04	0.04	18-21	8-11	

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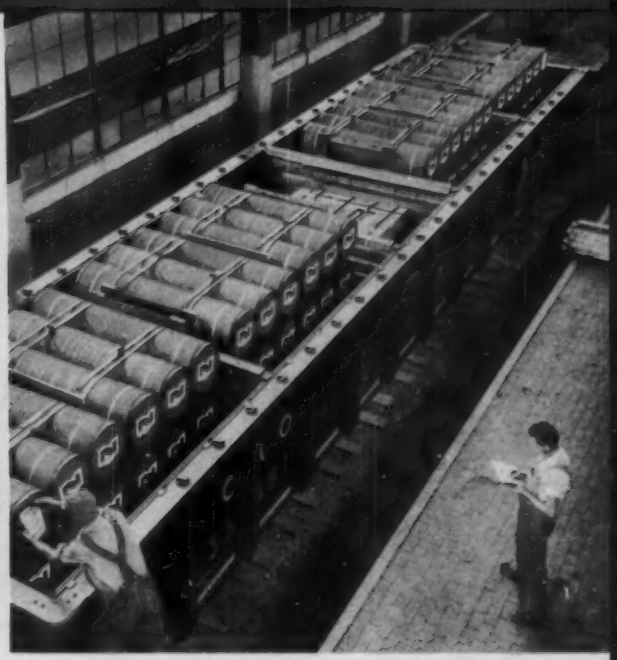

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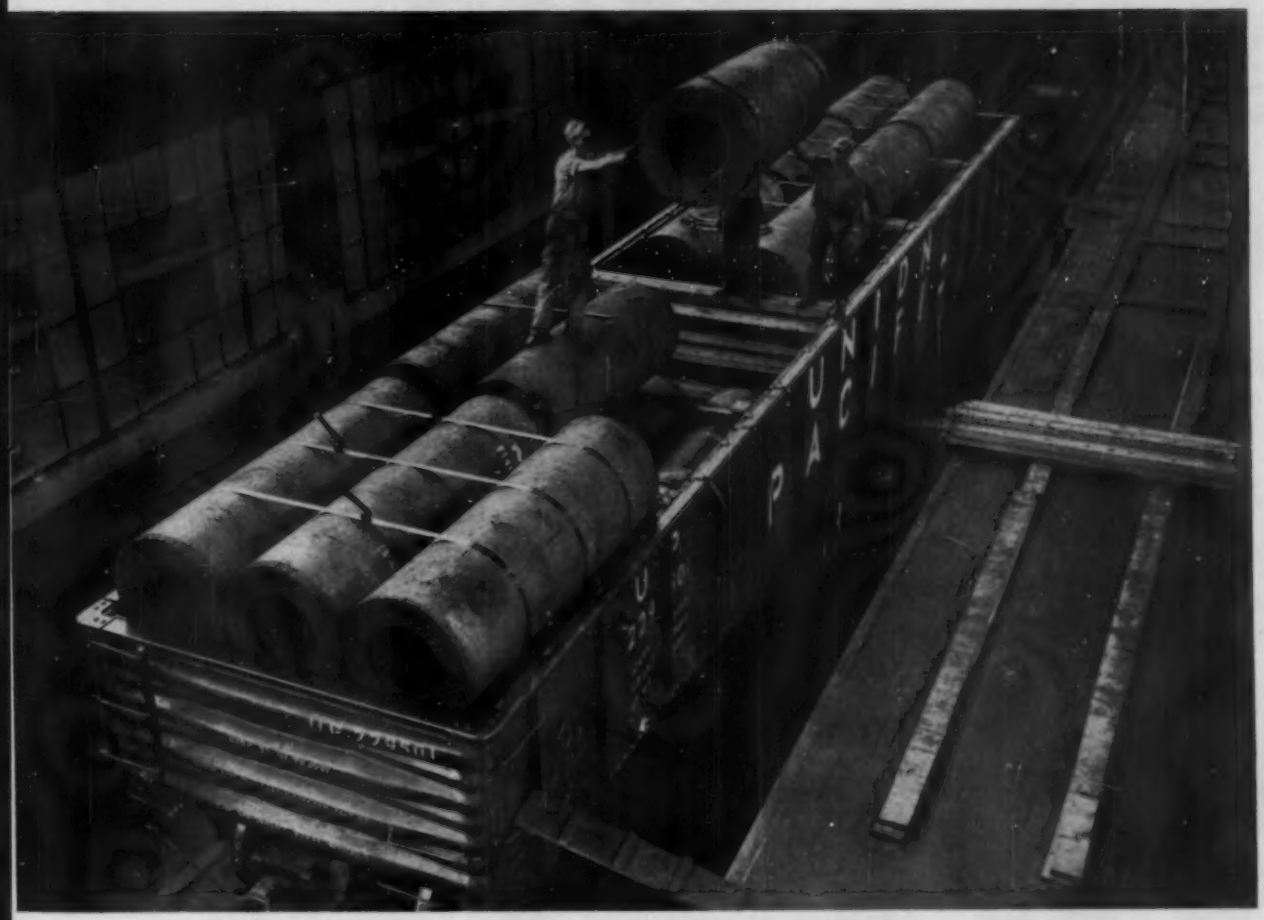

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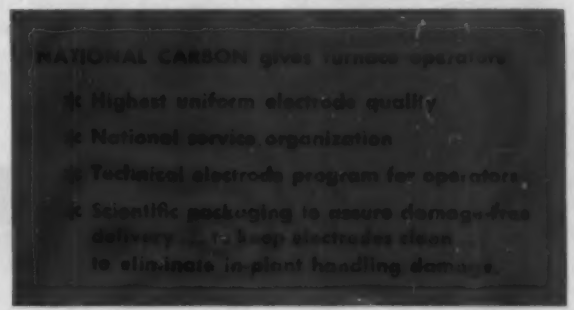
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Powder Metallurgy of Zirconium-Uranium Alloys

Digest of "The Powder Metallurgy of Zirconium-Uranium Alloys", by Herbert S. Kalish, Preprint No. 30, 1957.

ZIRCONIUM-URANIUM alloys were prepared by powder metallurgy methods at compositions throughout the binary system. The powders used were zirconium hydride obtained by hydriding iodide metal at 800° C. (1470° F.), and uranium powder obtained by hydriding the massive metal at 225° C. (440° F.), decomposing the UH_3 at 445° C. (830° F.) and pulverizing in argon. Both powders were −325 mesh with large proportions of fines, and contained 0.2 to 0.3% O_2 and 0.01% N_2. Powder mixes were weighed out and bottle tumbled for 2 hr. in an argon dry box, pressed to slabs $3 \times \frac{1}{4} \times \frac{1}{8}$ in., and sintered in a covered graphite boat in a sillimanite tube in a vacuum of the order of 2×10^{-5} mm. Hg; temperatures were within the range 1120 to 1320° C. (2050 to 2410° F.), and times 3 or 10 hr. All the sintered specimens had a bright, metallic appearance, but high-uranium alloys tarnished after a few days in air. Alloys containing less than 20% uranium could be pressed in air without significant oxygen pickup.

The use of UH_3 powder was found undesirable, since it oxidized in air at all compositions, and a lower sintered density was obtained. This was attributed to the extreme fineness of the hydride powder, and the high sintering shrinkage (40 to 45% by volume) due to the large volume change on the decomposition of UH_3 to U. The homogenization of the alloys was also slower than that observed using uranium powder.

The densification of the alloys, which is diffusion dependent in the solid solution range – above 860° C. (1580° F.) – was rapid, no liquid phase being formed even at sintering temperatures well above the melting point of pure uranium. The optimum sintering temperatures increase at higher uranium contents. When sintering above the solidus line, only slight deformation of the compact takes place if little liquid is present, but layer separation was observed when considerable melting

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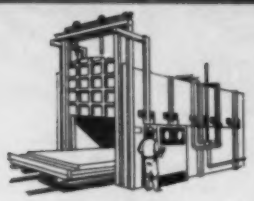

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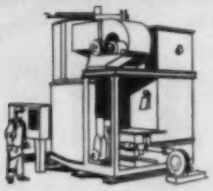

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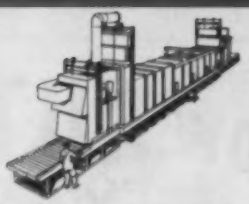

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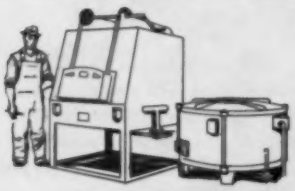

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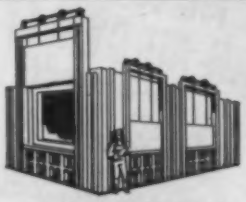

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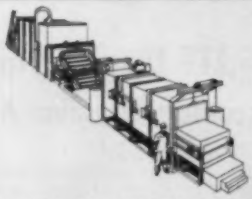

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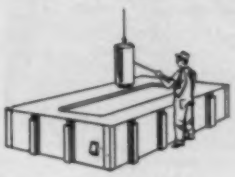

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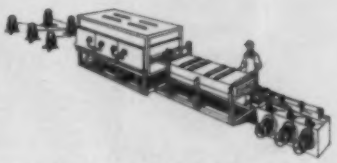

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Zr-U Powder Alloys . . .

occurs, due to the large density differences between the liquid and the solid. At uranium contents above 80% the sintering must be done immediately below the solidus, since excessive melting takes place at higher temeratures, while no appreciable sintering occurs at lower temperatures. Optimum sintering temperatures are tabulated.

All the alloys homogenized rapidly, and the structures obtained were in general agreement with the published diagram. The existence of the intermediate phase γ was confirmed, as well as the two eutectoids. However, the location of the lower eutectoid is thought to be 610° C. (1130° F.) and near 20% uranium rather than the previously reported 60% uranium. No reason for this discrepancy is suggested. The grain size of the sintered alloys varied between 100 μ for the low, and 15 μ for the high-uranium alloys. Longer sintering time had little effect on the final grain size.

The electrical resistivity, hardness, ultimate tensile strength and ductility of the alloys were determined on as-sintered specimens. These properties confirm the eutectoid location near 20% uranium. The results obtained were:

1. Density – 6.51 to 16.81 g. per cc. at 0 to 95% U.
2. Hardness – Rockwell A-55.5 through 69.9 to 39.6 at 0 through 80 to 95% U.
3. Ultimate tensile strength – 54,000 through 120,000 to 72,000 psi. at 0 through 80 to 95%.
4. Elongation – 12.2 to 17.5% on the as-sintered bars – no reduced gage section.
5. Resistivity – 61.1 through 167 to 46.2 micro-ohm-cm. at 0 through 40 to 95% U.

All the alloys can be both hot and cold worked. The structures obtained are illustrated with photomicrographs, and the alloy properties tabulated and illustrated by graphs for the full composition range.

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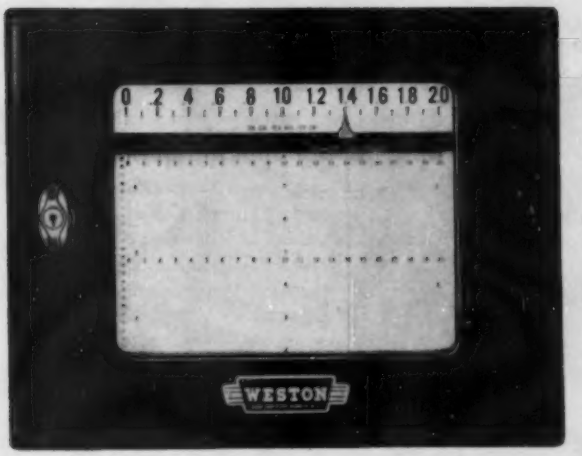
TTT Diagrams for Zirconium-Uranium Alloys

Digest of "Transformation Kinetics of Zirconium-Uranium Alloys", by D. L. Douglass, L. L. Marsh, Jr., and G. K. Manning, Preprint No. 20, 1957.

THE TIME - TEMPERATURE - transformation diagrams for zirconium - uranium alloys were determined. The transformation kinetics of zirconium alloys containing 8.85, 11.1, 14.3, and 20.7% uranium were studied by metallographic and X-ray diffraction techniques.

Crystal-bar zirconium and center-cut biscuit uranium were double-arc melted in vacuum in water-cooled copper crucibles. The ingots thus formed were forged at 800°C. (1470°F.) and were then rolled to ½-in. rounds at 750°C. (1380°F.).

Specimens were heat treated in two manners: Isothermal - transformation specimens were sealed in Type 304 stainless steel tubes and suspended in a salt bath at 950°C. (1740°F.) for 1 hr. to insure that



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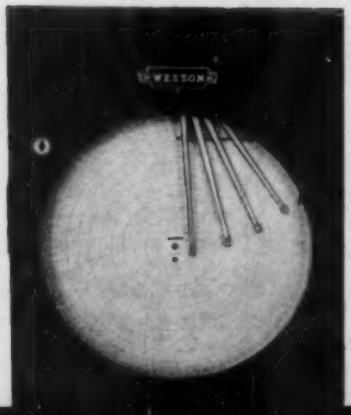

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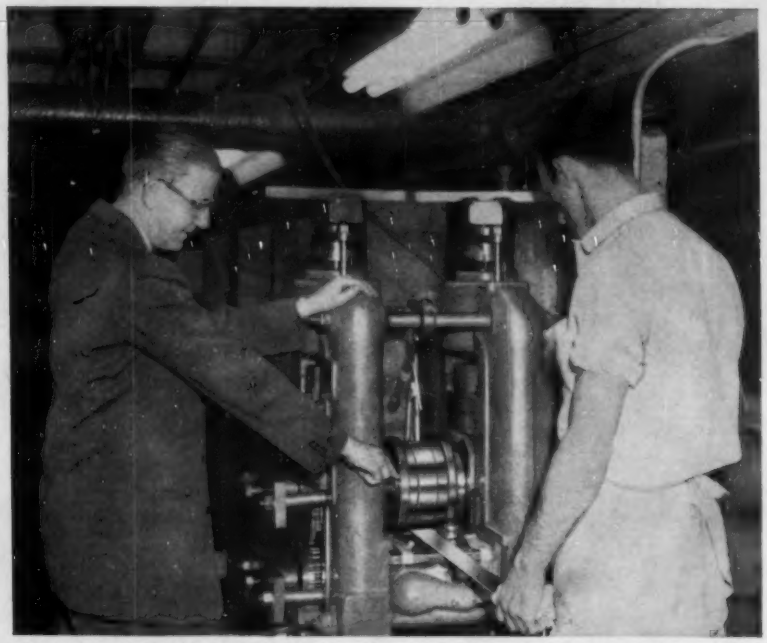

Cold rolling of critical heat resisting alloy stator vanes at D.E. Makepeace Company, Attleboro, Mass.

Vulcan Service PLUS TCM Steel solves tough rolling problem on jet stator vanes

Vulcan sales engineers, working closely with the tool experts of D. E. Makepeace, faced a tough and exacting problem: How to increase the service life of rolls used in cold rolling critical jet engine heat resisting alloy stator vanes.

As a result of joint investigations, design changes were recommended and adopted. The result? Roll life was multiplied.

Vulcan engineers went further. Despite the fact that other grades of tool steel had been tried and found unsatisfactory, Vulcan engineers predicted that *additional* improvements could be made by using Vulcan TCM steel. This recommendation, too, was adopted. The result? The already increased roll life was *trebled*. Net result: substantial savings with increased roll life, less down time and greater productivity.

This same engineering help is available to you without charge. For the name of your nearest Vulcan representative, write, wire or call collect. Vulcan Crucible Steel Division, H. K. Porter Company, Inc., Aliquippa, Pa.

H. K. PORTER COMPANY, INC.

VULCAN CRUCIBLE STEEL DIVISION

Zr-U Transformations . . .

the alloys were single-phase (beta) at the end of the solution treatment. An isothermal treatment was achieved by quenching the capsules into an intermediate salt bath maintained at the desired temperature and by holding for a given time and then water quenching to room temperature. Also, studies by direct quenching were made on samples sealed in evacuated Vycor tubes which were solution treated and quenched immediately in ice water. The martensitic transformation of alpha zirconium was detected by the thermal arrest disclosed by a gas quenching technique similar to that used by Greninger.

Diffraction patterns by back-reflection methods were obtained from rotating silver specimens using manganese radiation. High-temperature diffraction patterns from a thin silver sample were also made in a vacuum camera. TTT-curves were drawn on the basis of metallographic examination correlated with X-ray diffraction results. Transformation of beta to alpha proceeded rapidly within 1 min. for all alloys. The knee of the curves occurred between the beta/beta + alpha transus and the eutectoid temperature for all alloys. Increasing the uranium content retarded the initiation of the reaction at the knee from 10 sec. to about 60 sec. for the 20.7% uranium alloy. At all of the eutectoid temperatures, increasing the uranium content was even more effective in retarding alpha precipitation. The alpha precipitate was coarser with the higher transformation temperatures and appeared to coalesce and coarsen when the specimens were held isothermally for extended periods of time. The alpha formed at 650° C. (1200° F.) during 120 min. exposure, however, was barely resolvable at 1000 ×.

The curves extended below the eutectoid temperature until they intersected either the M_s, B_s (bainite-start temperature), or the $\acute{E}_s$ (start of epsilon prime transformation). In the alloys of higher uranium content, precipitation of alpha zirconium was retarded and precipitation of supersaturated epsilon, an intermediate phase ($\acute{E}$), was accelerated. The epsilon prime phase formed during the final quench

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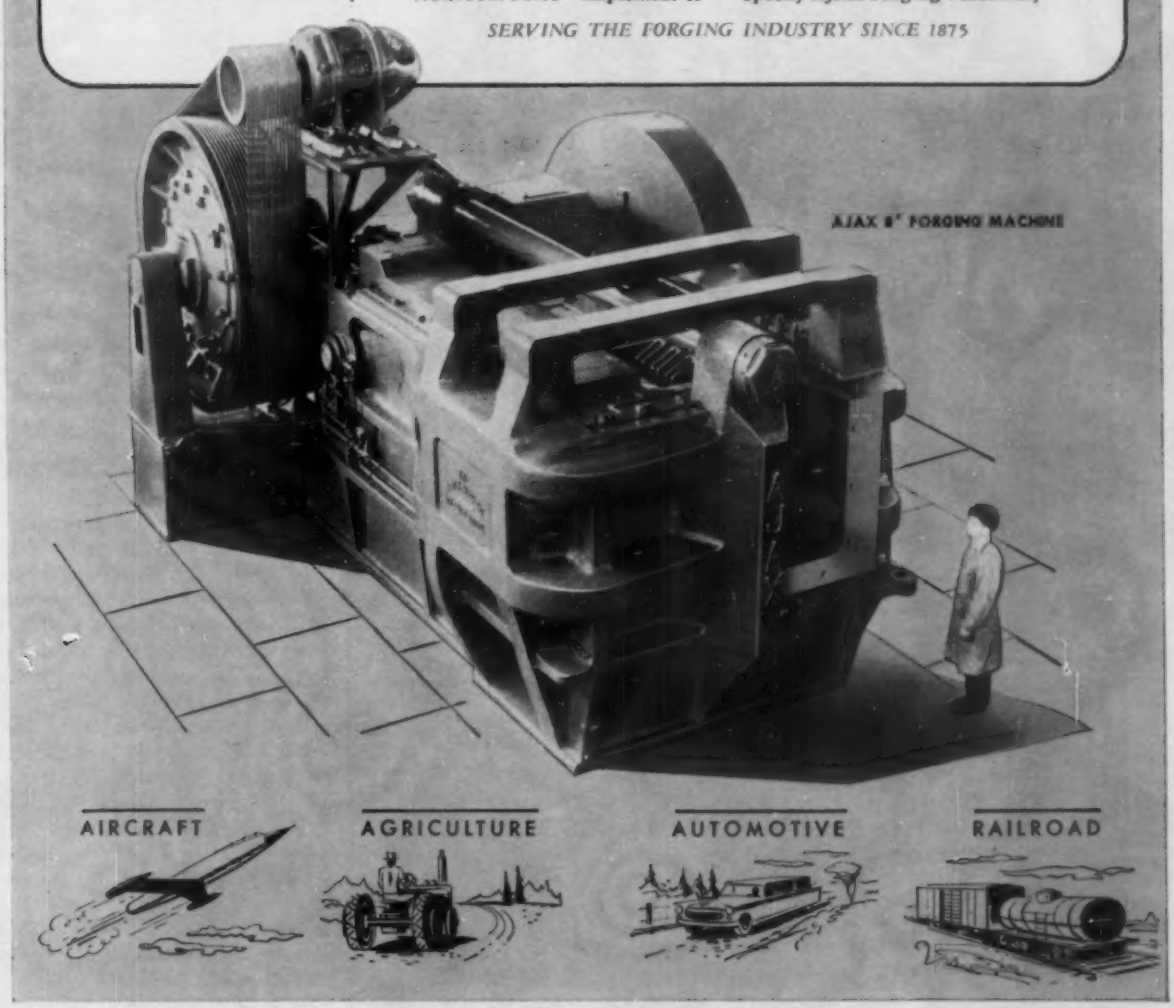

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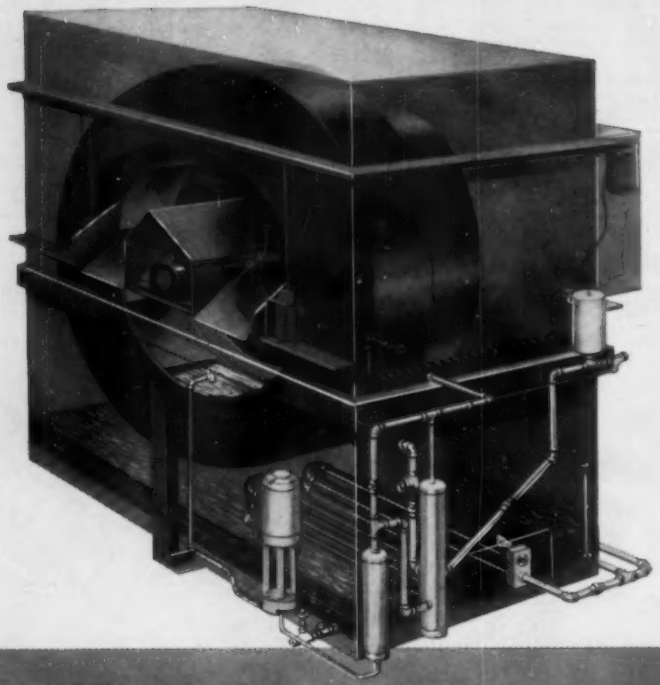

Outstanding new type Rotary Drum Degreaser saves space, cuts costs, needs only small investment

Combining solvent degreasing with automated work handling, the new DETREX 1DD750 provides thorough cleaning of such products as nuts, bolts, fasteners, stampings and screw machine parts. In-process cleaning—cleaning before and after heat treatment—cleaning before plating, phosphatizing, bright dipping, etc. —final cleaning—all are handled with important savings in initial investment, operating costs and space requirements.

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Zr-U Transformations . . .

from about 750° C. (1380° F.), which was indicative of beta enrichment during alpha precipitation of the 8.85% uranium alloy. Transformation of the 11.1% alloy produces similar structures as observed in the 8.85% alloy.

The matrices of the alloys studied consisted of epsilon prime while the general type of precipitate which dominated microstructures was alpha precipitation formed by a Widmanstätten mechanism.

During direct quenching from the beta region to room temperature, the three alloys containing the lowest uranium contents transformed to a martensitic alpha, designated alpha prime. Alapha prime is a distorted supersaturated, closely packed hexagonal alpha zirconium.

No alpha prime was observed in the 20.7% alloy under the quenching conditions, although it has been reported by other workers. It is believed, however, that the alpha prime had the uranium content of the beta phase from which it formed.

Traces of epsilon prime were detected in samples quenched from 1000° C. (1830° F.). The nature of the epsilon prime phase is controversial. It appears to form very rapidly and could nucleate either athermally or isothermally.

The degree of supersaturation believed to exist in alpha prime would seemingly involve a hardening reaction due to the formation of martensite. Little hardening, however, was observed and this result may be explained by the lack of coherency between alpha prime and parent beta phase. The small amount of hardening observed might be traceable to oxygen contamination. The highest uranium content to form alpha prime was the 14.3% alloy. An appreciable amount of epsilon prime was formed along with alpha prime. Alpha formed prior to epsilon in all four of the alloys investigated. Consequently, epsilon was probably formed from a beta phase enriched in uranium. Therefore, the precipitation of epsilon was restricted to a rather narrow temperature range for times less than 6000 min. The precipitation of epsilon initiated within 6 to 10 min. in the range of about 550 to 590°C.

(*Continued on p.* 290)

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PRODUCT	Formula	Atomic No.		
Scandium	Sc	21		
Scandium Oxide	Sc_2O_3			
Yttrium	Y	39		
Yttrium Oxide	Y_2O_3			
Lanthanum	La	57		
Lanthanum Oxide	La_2O_3			
Cerium	Ce	58		
Cerium Oxide	CeO_2			
Praseodymium	Pr	59		
Praseodymium Oxide	Pr_6O_{11}			
Neodymium	Nd	60		
Neodymium Oxide	Nd_2O_3			
Samarium	Sm	62		
Samarium Oxide	Sm_2O_3			
Europium	Eu	63		
Europium Oxide	Eu_2O_3			
Gadolinium	Gd	64		
Gadolinium Oxide	Gd_2O_3			
Terbium	Tb	65		
Terbium Oxide	Tb_4O_7			
Dysprosium	Dy	66		
Dysprosium Oxide	Dy_2O_3			
Holmium	Ho	67		
Holmium Oxide	Ho_2O_3			
Erbium	Er	68		
Erbium Oxide	Er_2O_3			
Thulium	Tm	69		
Thulium Oxide	Tm_2O_3			
Ytterbium	Yb	70		
Ytterbium Oxide	Yb_2O_3			
Lutetium	Lu	71		
Lutetium Oxide	Lu_2O_3			
Thorium	Th	90		
Thorium Oxide	ThO_2			

NOTES: (1) Index of Refraction — Cerium 2.33-2.35, Thorium 2.20 (lg), (2) Dielectric Constant — Cerium 7.0, Thorium 10.6, (3) Linear Elasticity Modulus — Lanthanum 3.820 Kg/mm²

PROPERTIES OF RARE EARTHS AND THORIUM

	Formula Wt.	Density	M.P. °C	B.P. °C	Oxide States	Ionic Radius	Normal Color	Δ H. VAP. (Kcal/mole)	Δ H. FUS. (Kcal/mole)	Crystal Stru.	Trans. Temp. °C	Brinnel Hardness	Compressibility (Cm^2/Kg x 10^6)	Neutron Absorption Cross-Sect. (Barns)	Electric Resist. (Microhm—cm. 25°C)
	45.10	3.016	1550-1600	2477	III			73	3.8	h. c. p.				22	
	138.20	3.86				1.51	White								
	88.92	4.472	1552	3027	III			80	4.1	h. c. p.			2.96	1.38	
	225.84	4.8-5.0	2410			1.06	White			Cubic					
	138.92	6.162	920	4242	III			81	2.4	Hex f. c. c.	300-350 868	37	4.06	8.9	56.8
	325.8	6.51	2315			1.22	White			Hex					
	140.13	6.768	804	2927	III, IV			79	2.2	f. c. c.	754	28	3.87	.70	75.3
	172.1	7.3	2600			1.18	White			Cubic					
	140.92	6.769	935	3017	III,(IV)			79	2.4	Hex	798	25	3.67	11.2	68.0
	1021.5					1.16	Black			Cubic					
	144.27	7.007	1024	3177	III			69	2.6	Hex	868		3.19	46	64.3
	336.5	7.24				1.15	Lt. Blue			Hex					
	150.35	7.540	1052	1627	(II), III			46	2.6	Rhom	917		3.71	5500	
	348.7	7.43				1.13	Off-White			Cubic					
	152.0	5.168	<900	1427	(II), III			40	2.5	b. c. c.				4600	
	352.0	7.42				1.13	White			Cubic					
	157.26	7.868	1350	2727	III			72	3.7	h. c. p.			2.58	46000	
	362.5	7.407				1.11	Yellowish Brown			Cubic					
	158.93	8.253	1360	2527	III,(IV)			70	3.9	h. c. p.	1310			44	
	747.7					1.09	Dk. Brown			Cubic					
	162.51	8.556	>1400	2327	III			67	4.1	h. c. p.			2.74	1100	
	373.0	7.81				1.07	White			Cubic					
	164.94	8.799	1500	2327	III			67	4.1	h. c. p.			2.66	64	
	377.9					1.05	Lt. Yellow			Cubic					
	167.27	9.058	1500-1550	2627	III			70	4.1	h. c. p.			2.63	166	
	382.5	8.640				1.04	Rose-red			Cubic					
	168.94	9.318	1550-1600	2127	III			56	4.4	h. c. p.			2.72	118	
	385.9	8.6				1.04	Greenish White			Cubic					
	173.04	6.959	824	1527	(II), III			40	2.2	f. c. c.					
	394.1	9.2				1.00	White			Cubic	798		8.00	36	
	174.99	9.849	1650-1750	1927	III			59	4.6	h. c. p.			2.32	108	
	398.0					0.99	White			Cubic					
	232.05	11.2	1845	4500	IV					f. c. c.	225	75-80 VPN		7	18.6 (20°C)
	264.12	10.03	3050	4400		1.80-1.82	White			Cubic					

REFERENCES: (1) C. J. Gorter, Progress in Low Temp. Physics, North Holland Pub. Co., Amsterdam, 2, 370-371 (1957), (2) Donald J. Hughes and John A. Harvey, Neutron Cross Sections, Brookhaven National Lab. (1955), (3) F. H. Spedding, A. H. Daane and K. W. Herrmann, J. Metals, 9, 895 (1957). For general bibliography see Reference No. 1.

The above data have been compiled from the literature and are believed to be the most accurate available. Heavy Minerals Co. can assume no responsibility, however, for any errors in the data or the compilation.

Zr-U Transformations . . .

(1020 to 1090°F.) for the 20.7% alloy. For times less than 6 min., alpha precipitated first and epsilon prime formed during the final quench. Alpha precipitated in a Widmanstätten pattern within the prior beta grains. The remaining beta transformed to a fine-grained structure of epsilon prime. No epsilon or alpha was observed in the 20.7% alloy at low temperatures and long times of exposure.

The conclusions reached from the investigation were:

1. Alpha precipitation was strongly retarded by increased amounts of uranium, particularly at temperatures in the range of 350 to 500°C. (660 to 930°F.).

2. Alpha prime (martensitic alpha) formed during a direct quench from beta region to room temperature in alloys containing up to 14.3% uranium. No alpha prime was observed in the 20.7% alloy.

3. A supersaturated epsilon was formed by direct quenching from the beta region. The transformation appears to be nucleated very rapidly under isothermal conditions or may possibly nucleate athermally.

4. Bainitic alpha formed in alloys containing 8.85 and 11.1% uranium during isothermal transformation below 550°C. (1020°F.).

5. Equilibrium epsilon formed isothermally at temperatures below the eutectoid after alpha precipitation had occurred.

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Ductility of Forged Electrolytic Chromium

Digest of "The Mechanical Properties of Forged Chromium", by S. A. Spachner and W. Rostoker, Preprint No. 48, 1947.

THE CHIEF PROBLEM with chromium and chromium-base alloys is development of adequate low-temperature ductility. The authors investigated the ductility of forged electrolytic chromium, particularly as affected by melting and forging practice and test variables. The beneficial effects of prestraining at elevated temperatures and grain refinement were demonstrated.

Work was done on a laboratory grade of electrolytic chromium containing 0.56% oxygen and 100 ppm. each of nitrogen and carbon, and 70 ppm. iron. A limited amount of work was done on a standard electrolytic grade containing 0.55% oxygen, 300 ppm. nitrogen, 200 ppm. carbon, and 0.17% Fe, and a low-oxygen grade (treated with hydrogen) containing 150 ppm. of oxygen, 100 ppm. nitrogen, and 100 ppm. carbon.

Most of the work was done on inert-gas (presumably argon) arc-melted chromium. The effect of melting current was important, since at low currents the material tended to form cold shuts on the surface while at high melting currents an excessive tendency for vaporization resulted in voids and holes where chromium vapor had condensed during solidification.

Forging was generally started at 2450° F. and finished at 1900° F.

(*Continued on p. 294*)

Shown is a Drever Gas-Fired Strip Belt Conveyor Furnace for reducing and drying copper powder at the rate of 10 tons per 24 hours at 1000°F.

In the foreground is a Drever Inert Gas Generator for supplying the necessary gases to purge the furnace entry and exit areas.

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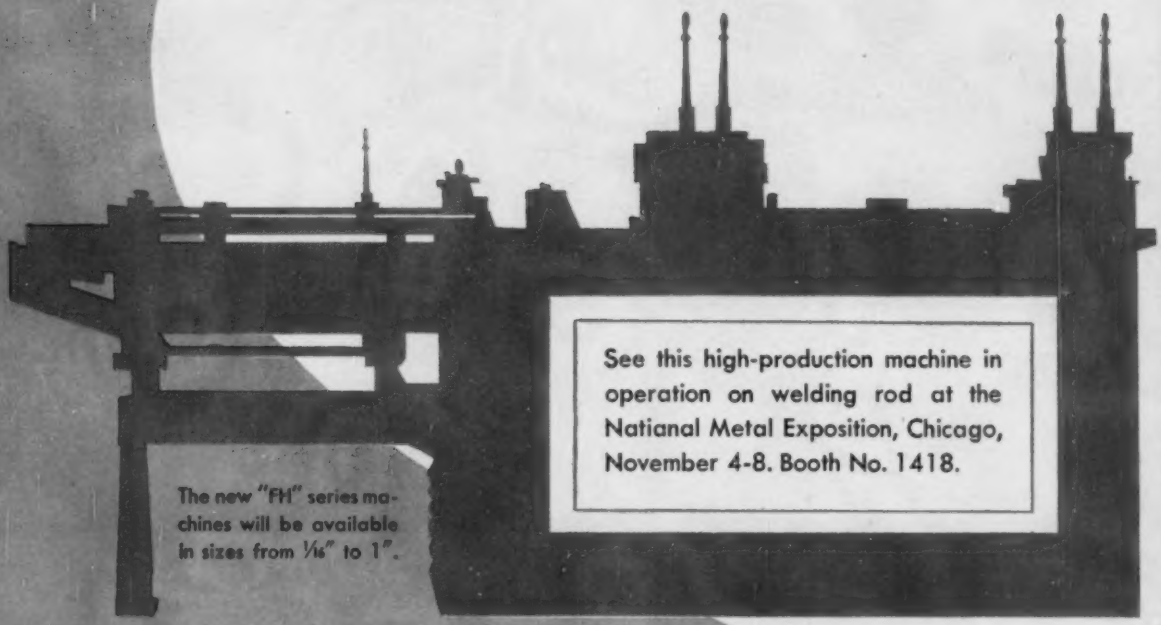

The new "FH" series machines will be available in sizes from 1/16" to 1".

See this high-production machine in operation on welding rod at the Natianal Metal Exposition, Chicago, November 4-8. Booth No. 1418.

For many years the Lewis Travel-Cut has been the "Standard of the Industry" in wire straightening and cutting machines.

Now, a new principle of shear operation makes possible much higher production with feed speeds up to 300 ft. per minute.

Through simplified design a smooth, positive-action, high-speed shear actuating mechanism is attained without the use of loose links, cams or springs.

This new cut-off in conjunction with an air clutch and a variable speed drive, permits perfect synchronization with the wire at all feed speeds.

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THE NEW **LEWIS** *Convertible*

AUTOMATIC WIRE STRAIGHTENING AND CUTTING MACHINES WITH VARIABLE SPEED DRIVE AND DUAL-CENTER STRAIGHTENER ARBOR

Front View No. 2CV4 ... Capacity 1/16" to 1/4" diameter. (No. 2CV5 capacity 1/16" to 5/16" diameter.)

✻ The new Lewis No. 2CV series is equipped with our Dual-Center Rotary Straightener Arbor and can be quickly converted to handle shapes by installing our interchangeable Roll Straightener.

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Other models available to handle .012" to 1" diameter, as well as shapes.

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Ductility of Chromium . . .

Strain rates were of exceptional importance. Hammer forging resulted in cracking, while press forging, starting with small bites until the structure was broken up, was much more successful. Even bar stock that had been successfully press forged could not be hammer forged without cracking.

The effect of temperature and strain rate on the strength and ductility of chromium was investigated using a torsion method. The shear stress in torsion is half that in tension; thus the state of stress for exhibiting ductility would be expected to be more favorable in such a means of evaluation. At temperatures above 250° C. (480° F.), torsion ductility was rather good in that at least two complete twists could be made before fracture. Exceptionally good ductility in torsion was noted at 1000° C. (1830° F.). Very low torsional ductility was obtained at temperatures below 150° C. (300° F.). The yield strength in torsion was relatively good up to 750° C. (1380° F.), but became quite low at 1000° C. (1830° F.). Strain-rate effects from 0.01 to 1 per min. were not found to be important.

The three grades of chromium were evaluated for ductility at 750° C. (1380° F.). There was no difference in forgeability between the grades, but, surprisingly, the commercial grade of chromium showed slightly better ductility than the others. A limited number of tensile tests were performed on the forged bars. They indicated excessive brittleness at room temperature and good ductility at temperatures above 500° C. (930° F.). The tensile strength of forged chromium at 500° C. (930° F.) was only about 37,000 psi. and decreased to 12,000 psi. at 1000° C. (1830° F.).

Transition temperatures of ductile to brittle behavior were determined by incrementally twisting the bars at successively lower temperatures until brittle fracture occurred. The base transition temperature of forged chromium (laboratory grade) was found to be 50° C. (120° F.). Unfortunately, the transition temperatures for the commercial and high-purity grades of chromium were not reported for comparison. The transition temperature invariably

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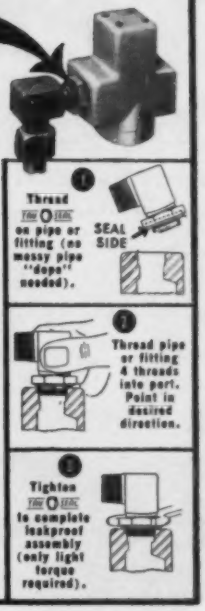
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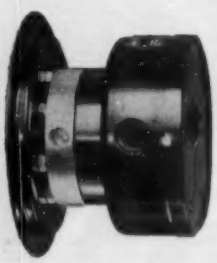

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Ductility of Chromium . . .

was increased to above 100° C. (212° F.) if a tungsten inclusion from the melting electrode was present. With 1.5% iron in solution, the transition temperature was above 100° C. (212° F.). Surprisingly, strain rate from 0.001 to 0.05 per min. had little effect on transition temperature.

Prestrains at 400 and 250° C. (750 and 480° F.) resulted in rheotropic recovery and reduction of the transition temperatures from 50° C. (120° F.) to room temperature or below. The optimum condition was 0.75 strain at 250° C. (480° F.), which resulted in a 0.11 torsion strain being permissible at room temperature. The prestrain could be applied in compression as well as torsion; 50% reduction at 250° C. (480° F.) was found to be effective. Grain refinement through the use of lower forging temperatures also was effective. With a 25 to 50% finish forging reduction by pressing at 1950° F. followed by 50% compression at 250° C. (480° F.), annealing at 1000° C. (1830° F.) for 10 min. to produce 0.03 mm. recrystallized grain size resulted in sufficient ductility at room temperature to permit a 41° twist before fracture. ROBERT JAFFEE

Stable Nickel-Free Stainless Steels

Digest of "Phase Relationship in Austenitic Cr-Mn-C-N Stainless Steels," by Chi-Mei Hsiao and E. J. Dulis, ⊕ Preprint No. 29, 1957.

THIS PAPER supplies additional information on nickel-free austenitic stainless steels. The stable austenitic region for steels containing 0.10 to 0.80% C, 10 to 28% Mn, 12 to 28% Cr and 0.10 to 0.80% N was determined. Microscopic and hardness surveys were made.

The experimental steels were melted in a 15-lb. induction furnace and forged to ⅝-in. bars. Bars were solution treated for 2 hr. at 1700 to 2500° F. and water quenched. These steels were then aged in the range of 1200 to 1600° F. for various times. Microstructures were determined after each treatment for delta ferrite and martensite, grain size and residual carbides and nitrides.

The work on phase relationships can be summarized as follows: At 2100° F. the minimum amount of carbon plus nitrogen required for a completely austenitic structure increases with increasing amount of chromium and this relationship was represented empirically by

$$(\%C+\%N)=0.078(\%Cr-12.5)$$

This equation fits the data for steels which contained 5 to 14% manganese. Little work was done on the higher - manganese steels. For higher-carbon steels (over 0.25%), the amount of delta ferrite formed decreased with increasing temperature in the range 1900 to 2500° F. For the lower-carbon steels (0.12%), the amount of delta ferrite first decreased, then increased with increasing solution temperature. Residual carbides and nitrides in solution treated steels decreased with increasing temperature.

Whether the austenite that formed after solution treating could be retained at room temperature and after aging depended upon the composition of the austenite. When the chromium was over 15%, about 12% manganese is required to stabilize the austenite to avoid martensite formation. When the chromium was between 12 and 15%, the amount of manganese required varied between 12 and 18%. The amount of manganese required depended also on the amount of chromium plus nitrogen in the steel. For lower chromium and carbon plus nitrogen contents, higher manganese is needed to stabilize the austenite. No formula is derived to predict the composition needed to prevent martensite formation.

Grain-boundary and general precipitation was found in steels that were solution treated and aged. The grain-boundary precipitation was found predominantly in high-nitrogen steels and was favored by higher aging temperatures. The general precipitation product was found predominantly in low-nitrogen high-carbon steels. Sigma phase was produced in some of the steels studied, largely by transformation of delta ferrite to sigma phase. The data are useful in designing stable nickel-free austenitic steels.

D. J. CARNEY

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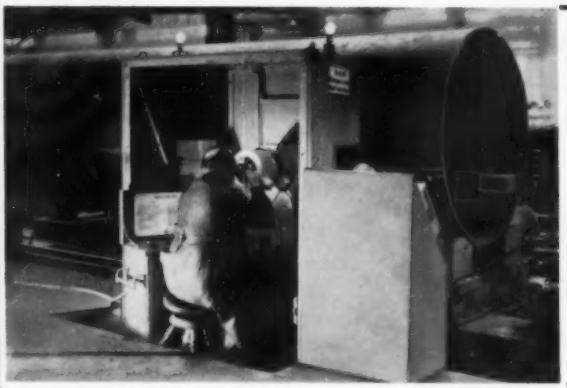
*It must be noted that these results were obtained with the use of a 0.4 mm., Norelco stationary anode fractional focus tube which provides unexcelled resolution and a constant potential source.



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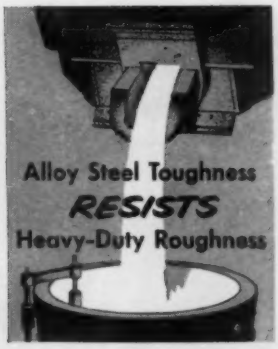

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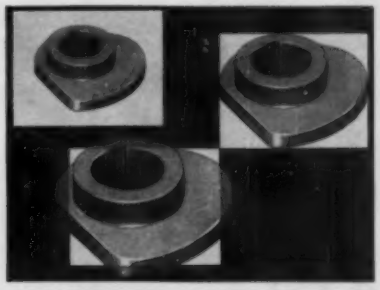

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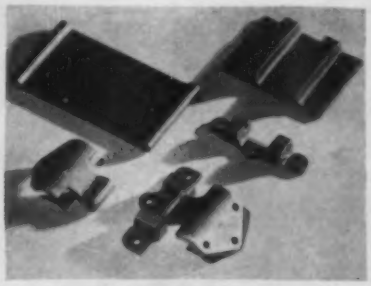

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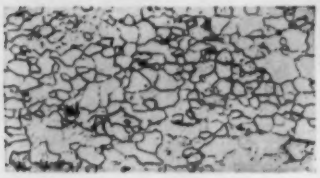

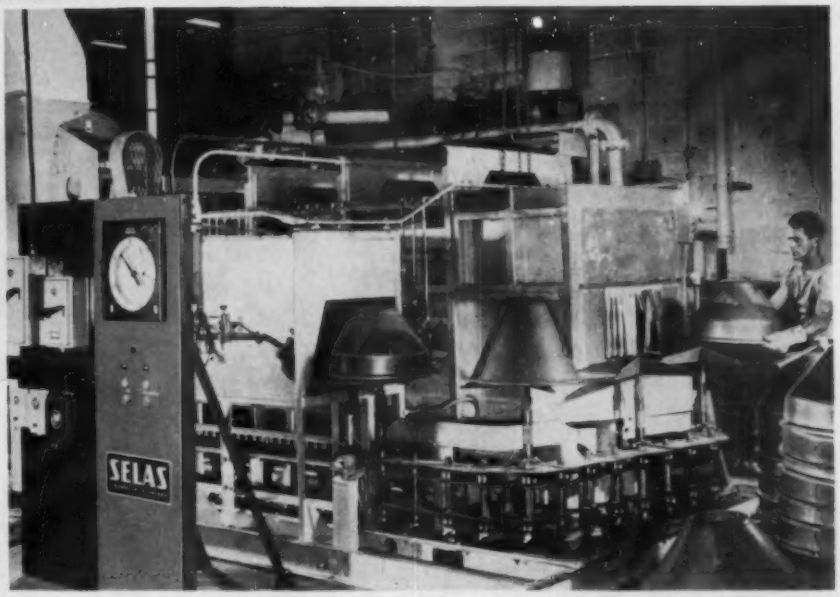

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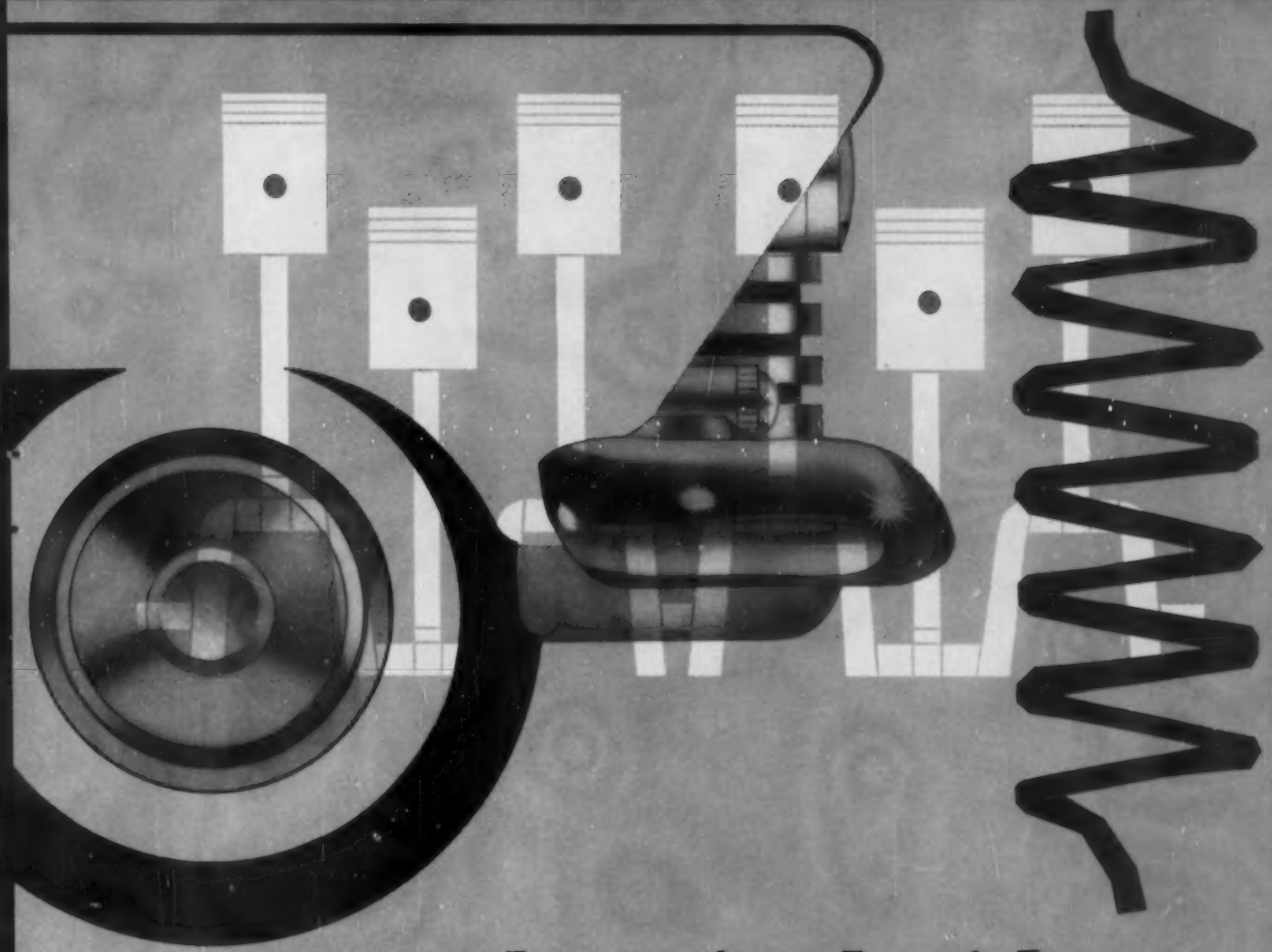

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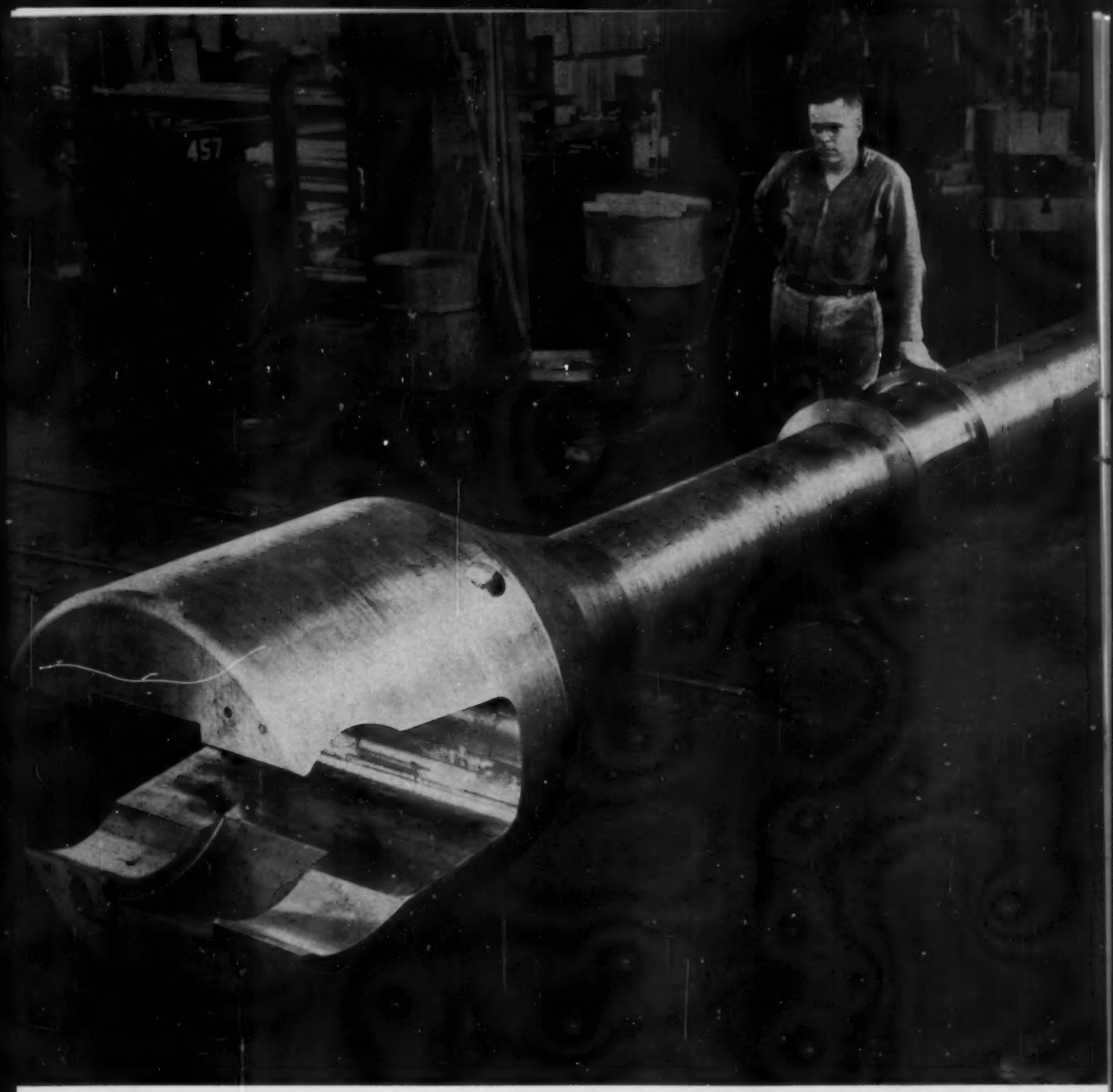

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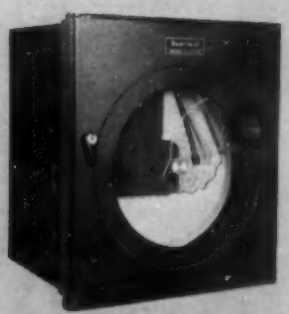

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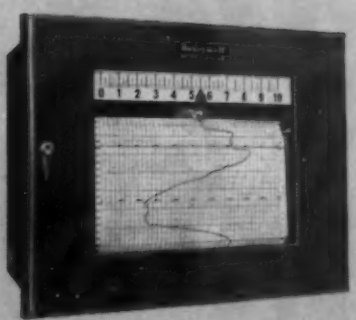
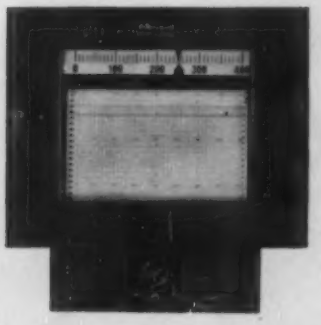


Strip Chart Recorder—Single or Multiple Point . . . Records all types of variables. Choice of pen speeds and chart speeds.

Precision Indicator—Circular Scale . . . Highly accurate indicator for all variables, one to 48 points.

Circular Scale Controller . . . Scale is over 2½ feet long. Control index rotates with scale for 12 o'clock control check. Available in all electric control forms.



Strip Chart Program Controller . . . Incorporates temperature indication, single or multiple recording, controlling—in one instrument.

STOP shopping . . .

Whether it's temperature, pressure, flow, or any other important variable you want to measure or control, Honeywell makes just the instrumentation for you. Our line of instruments is as broad as your requirements . . . you can choose exactly what you need.

This means you get all the instrumentation you require from a single source, so there is undivided responsibility for the complete installation. And you are assured that equipment suggested for your process is recommended without bias. With a complete line there is no need to over-sell or under-equip.

For the new process, the modernization program, or a replacement problem, find out how Honeywell can go to work . . . anywhere in the metal processing industry. Get in touch with your nearby Honeywell sales engineer. He's as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, Wayne and Windrim Avenues, Philadelphia 44, Pa.—in Canada, Toronto 17, Ontario.

Precision Indicator—Vertical Scale . . . Has drum-type power-driven scale. Full scale travel in 12 or 4½ seconds.

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when should you pay $13.00* a pound for TITANIUM?

The answer is *when its cost/life ratio makes titanium less costly than other metals*—as it often does. Look at it this way . . .

More Metal Per Pound—Titanium weighs only 56% as much as steel of the same strength. Where 50 pounds of steel is needed—28 pounds of titanium will do the job.

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Titanium Outlasts Most Metals—even those generally considered 'corrosion-resistant,' by 10, 20, even 50 times or more.

Added together, these facts often make titanium the most inexpensive material you can use. And only titanium can provide its exceptional combination of *light-weight, high-strength,* and *resistance to corrosion.* Ask a REM-CRU engineer to give you complete details about what titanium can do for you.

**The actual cost of titanium mill products varies with the grade, size and quantity ordered. The $13.00 figure is representative of today's prices for items used in commercial applications.*

Write Dept. MP-10 for the Rem-Cru Review—a free periodical presenting the latest data on titanium.

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The next time you're faced with a difficult and costly heat treating problem, call in the man whose training and experience qualifies him as "the man with the answers": your local representative of the Park Chemical Company. As a representative of Park Chemical, for 45 years producers of a complete line of quality heat treating materials, your Park man will help you decide which materials and methods are best suited to smooth out your heat treating operations.

Carburizing or hardening, heating or quenching, whatever the operation may be, the Park man will show you the Park product that will result in more efficient, less costly heat treating. On-the-job tests in plants all over the country have proven that Park heat treating materials mean less rejects, better finishes, and virtual elimination of production tie-ups.

Whenever a difficult heat treating operation threatens to tie-up your production, call in the Park man for on-the-job help. He's always available. Call him, or write us direct.

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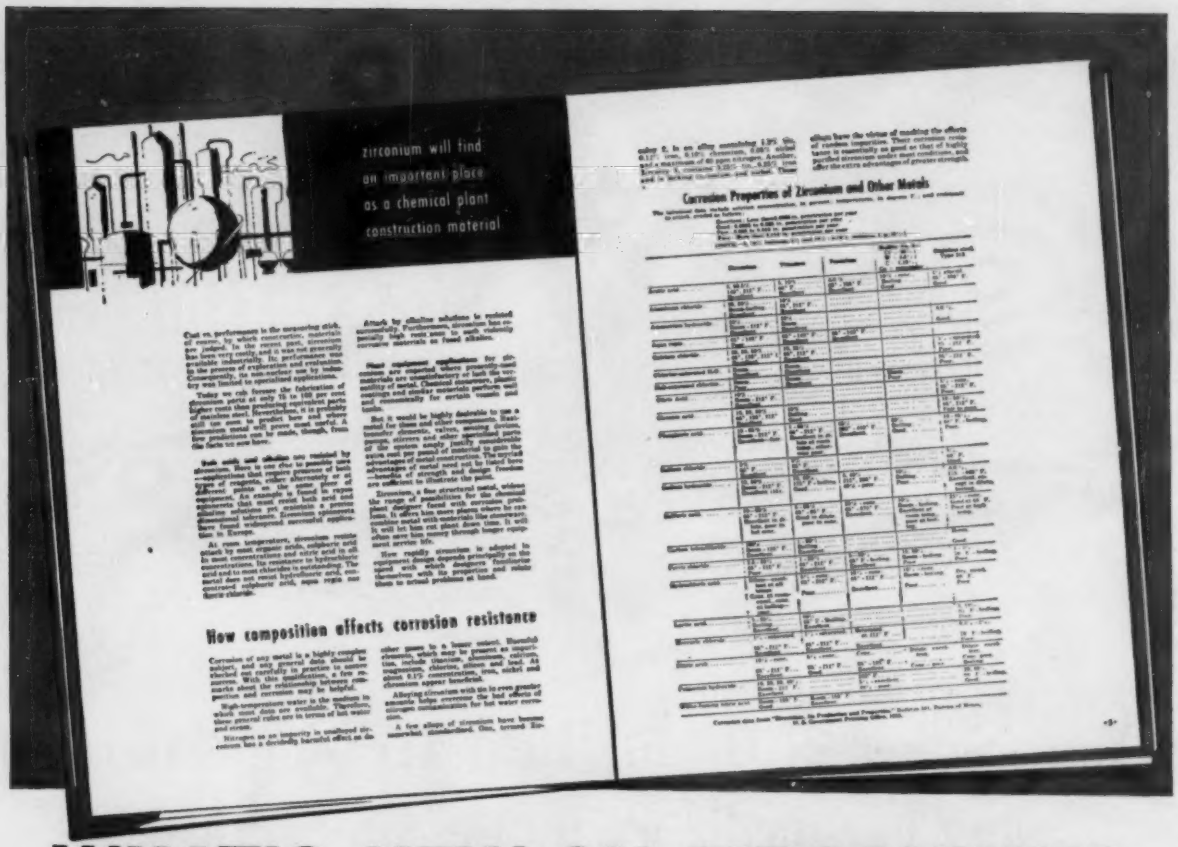

zirconium will find
an important place
as a chemical plant
construction material
How composition affects corrosion resistance
Corrosion Properties of Zirconium and Other Metals

WHAT'S NEW ON ZIRCONIUM?

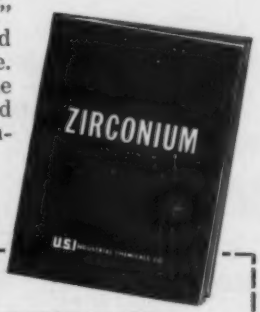
This U.S.I. booklet gives you information you can use . . . Send for a copy!

Today, with zirconium production trending sharply upward, and price downward, interest in this new and unique metal is growing rapidly.

To answer your questions about zirconium and its relative, hafnium, U.S.I. has prepared an informative new booklet — "ZIRCONIUM and HAFNIUM." The booklet gives the important facts on these newly available metals . . . lists important mechanical and physical properties of both . . . describes briefly the new semi-continuous sodium reduction process for production of zirconium and hafnium.

You'll find the outstanding corrosion properties of zirconium compared with other important metals... phase diagrams of twenty binary alloy systems . . . descriptions of several fabrication techniques.

You're sure to find "ZIRCONIUM and HAFNIUM" valuable in discussions and as a preliminary reference. For your copy, forward the coupon today . . . or just send your name on your company's letterhead.



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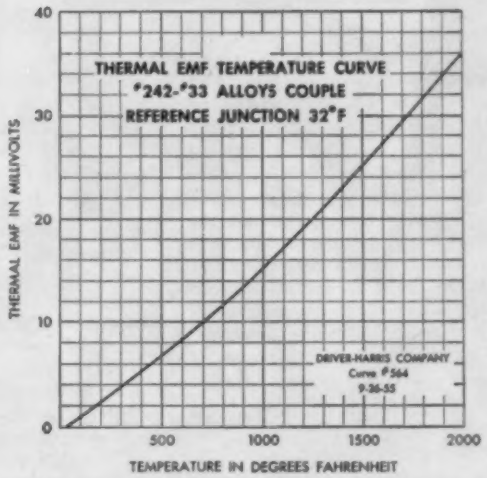
Driver-Harris Announces Major Advance in Pyrometry!

New #242-33 Thermocouple* for Reducing Atmospheres Maintains Calibration Through a Greatly Extended Life

This new Driver-Harris Thermocouple was developed primarily to withstand industrial reducing atmospheres at high temperatures and thereby to end the danger of runaway furnaces and ruined charges.

Unusually high resistance to "green-rot" attack is the outstanding property of the alloys of this thermocouple, whose analysis is:

Positive Leg (No. 242 Alloy)	Negative Leg (No. 33 Alloy)
80/20 Ni-Cr + Cb	3% Si-Ni



Although the thermal-emf response of this thermocouple is lower than the conventional thermocouple now in use, the slope of its temperature-emf curve is virtually parallel in the higher ranges of temperature in which both couples are designed to be used. Thus, the thermal-emf sensitivities are equivalent in the higher temperature ranges.

Tested against the conventional thermocouple in an atmosphere of the following nominal composition: CO...10%; CO_2...5%; CH_4...1%; H_2...16%; O_2...Nil; N_2...Balance (best for accelerating green-rot attack), exposure after 212 hours showed *only +0.13 mv. drift for the D-H thermocouple, and −7.54 mv. for the conventional thermocouple.*

When the thermal-emf of the conventional thermocouple *drops*, as in a reducing atmosphere such as this, the working temperature of the furnace controlled by it *rises*. However, when a #242-33 couple is used under the same conditions the thermal-emf remains substantially constant. This means that a furnace controlled with the new D-H thermocouple *cannot overheat and ruin charges.*

Members of the Heat-Treating and Instrument Manufacturing Industries are urged to investigate this new Driver-Harris Thermocouple without delay so that through their combined efforts all U. S. Industry can benefit. Complete technical data and application information is waiting for your inquiry. Write today to our Thermocouple Division.

*U. S. Patent No. 2,691,690

Driver-Harris COMPANY HARRISON, NEW JERSEY

BRANCHES: Chicago, Detroit, Cleveland, Louisville, Los Angeles, San Francisco In Canada: The B. GREENING WIRE COMPANY, Ltd., Hamilton, Ontario

MAKERS OF THE MOST COMPLETE LINE OF ALLOYS FOR THE ELECTRICAL, ELECTRONIC, AND HEAT-TREATING INDUSTRIES

Facts to consider when you're buying

Chromate Conversion Coatings

for Corrosion Protection, Paint Base, Decorative Finishing

WHAT IS IRIDITE®?

Briefly, Iridite is the tradename for a specialized line of chromate conversion finishes. They are generally applied by dip, some by brush or spray, at or near room temperature, with automatic equipment or manual finishing facilities. During application, a chemical reaction occurs that produces a thin (.00002" max.) gel-like, complex chromate film of a nonporous nature on the surface of the metal. This film is an integral part of the metal itself, thus cannot flake, chip or peel. No special equipment, exhaust systems or specially trained personnel are required.

If your company is manufacturing or buying parts or complete assemblies made from or plated with any of the more common non-ferrous metals—zinc, cadmium, aluminum, magnesium, silver, copper, brass or bronze—you've probably already run up against the question of finishing these surfaces with a chromate conversion coating. These coatings are used to protect against corrosion, or to provide a base for paint or to provide a decorative finish for sales appeal or shelf life. Since chromate conversion coatings represent a relatively new means of obtaining these finishes, this digest of facts to consider may be of value to you.

1. THE COATINGS THEMSELVES. There are many brands on the market. All are similar in many ways. Each, of course, offers its own specific advantages and these may relate to operating techniques, performance under actual use conditions, cost, availability, etc. Naturally, you'll want to choose a coating that is widely known and accepted under both military and civilian specifications.

2. THE COMPANY BEHIND THE PRODUCT. Is it a reliable, established organization? Does it offer experienced technical service, both from the field-engineering organization as well as the home office and laboratories? The man who sells and services your installation should be thoroughly familiar with not only chromate conversion coatings and their applications, but also with the characteristics and performance of related finishing operations such as precleaning, electroplating, painting, etc. This is most important since all steps of the finishing cycle must be functioning properly for the satisfactory performance of the ultimate finish produced.

3. AVAILABILITY OF THE PRODUCT. Ideally, of course, the material should be readily available to you from nearby warehouses to avoid time loss in long distance shipping and to provide emergency service, should the need arise.

4. COST. Naturally, the initial price of the material is important to you. However, just as you consider ultimate cost when you are buying mechanical equipment, ultimate cost must be considered for these finishing chemicals. So, it will pay you to investigate consumption costs, labor costs and the other factors which go into the determination of ultimate cost. Further, cost alone gives no indication of product performance, so careful attention must be given to the purpose the finish must serve and the value that finish will add to your product.

5. FACILITIES FOR RESEARCH AND DEVELOPMENT. Perhaps the existing types of chromate conversion coatings do not include a compound that will accomplish exactly what you wish. Then, it is important to deal with a supplier who has adequate research and development facilities available to work with you to produce a material to meet your needs. Naturally, such a project is seldom completed overnight. But, with complete cooperation and confidence from both you and your supplier, chances are a satisfactory program can be completed.

These are the concepts of sales and service on which we, Allied Research Products, Incorporated, have developed and marketed the line of Iridite chromate conversion coatings . . . superior product performance, complete sales and technical service, easy product availability, economical cost, extensive research and development facilities. No doubt you are familiar with our line and have seen this trademark—

IRIDITE®

—in our advertising, technical literature or on shipping containers in your plant. Remember this trademark when you're buying or investigating chromate conversion coatings for your company. It's your assurance of quality, economical products from a reliable and established company, skilled sales and technical service from both our home office and a national network of representatives, immediate availability from warehouses in strategic industrial areas and our willingness to work with you to develop new finishes to meet your needs, should the present line fall short.

For complete information on Iridite chromate conversion coatings, write today for your free copy of our technical data file. Or, for immediate advice, call in your Allied Field Engineer. He's listed under "Plating Supplies" in your classified telephone book.

ALLIED RESEARCH PRODUCTS
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Manufacturers of Iridite chromate conversion coatings for corrosion resistance, paint systems, final finishing of non-ferrous metals; ARP Plating Brightener & Chemicals. West Coast Licensee—L. H. Butcher Co.

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HOT DIP ALUMINIZING PROCESS

for Protection Against Corrosion and Heat Oxidation in—

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Alumicoat molten aluminum process

The Alumicoat Molten Aluminum Process will substantially reduce down time and expense for repairs and replacements by preventing high temperature [illegible] and scaling [illegible] equipment.

In addition [illegible] by the use [illegible] which, [illegible] the necessary [illegible] temperatures.

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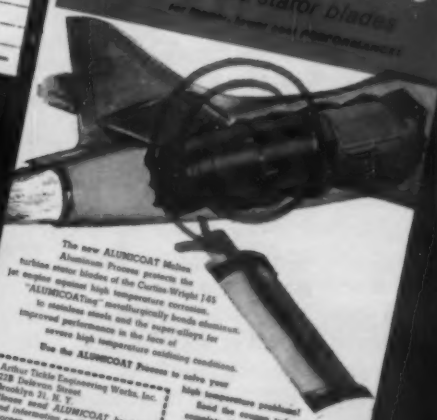
NO. 5 in a series on ALUMICOAT APPLICATIONS
WRIGHT Alumicoats
turbine stator blades



The new ALUMICOAT Molten Aluminum Process protects the turbine stator blades of the Curtiss-Wright J65 jet engine against high temperature corrosion. "ALUMICOATing" metallurgically bonds aluminum to stainless steels and the super-alloys for improved performance in the face of severe high temperature oxidizing conditions.

Use the ALUMICOAT Process to solve your high temperature problems! Send the coupon today for complete details.

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NO. 6 in a series of ALUMICOAT APPLICATIONS
transition welding made possible with the new
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Hot Dip Aluminizing Process

Pressure-tight welds of mild steel and stainless steel to Aluminum are now possible with the ALUMICOAT Molten Aluminum Coating Process! By first "ALUMICOATing" the steel, the Metallurgically bonded overlay of aluminum provides the necessary base for welding aluminum alloys to the steel!

This is just one of the many applications of the ALUMICOAT Process now available to industry. For complete details send the coupon today!

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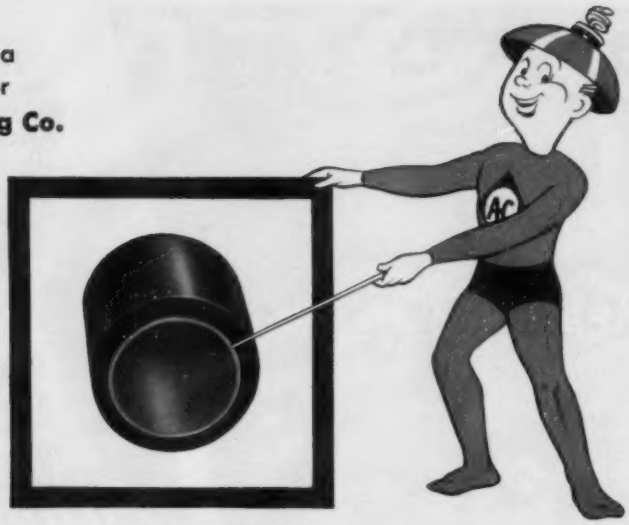
Mr. Hi Frequency does a
Surface Hardening Job for
Jambor Tool and Stamping Co.



Boosts Bolt Sales 300%

White line indicates hardened steel. A uniform case depth of .060 with Rockwell hardness of 60 to 62 is obtained. (Black wrapper was used in photo to emphasize hardened area.)

Jambor had trouble. They were making a top-grade king bolt with excellent wearing qualities, but it had one little drawback — *it was "file soft."*

Mr. Hi Frequency to the Rescue

To remedy the situation, Jambor switched to a higher carbon steel and surface-hardened the bolts with Allis-Chalmers electronic induction heaters. Mr. Hi Frequency's rapid and selective method of surface hardening produced amazing results. Sales went up a whopping 300%. Material costs dropped 10%.

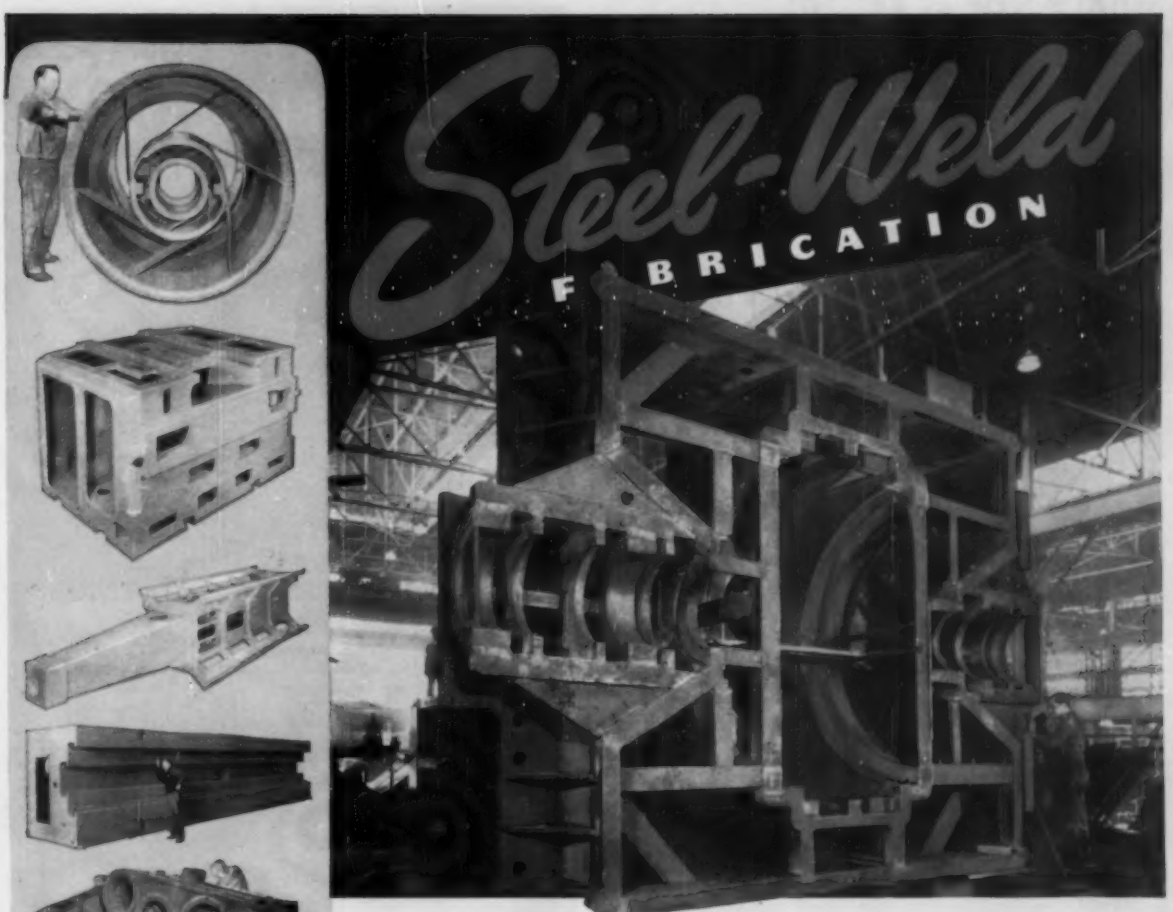
It could happen to you. If your job is one of hardening, annealing, soldering, brazing or melting, it will pay you to consider Allis-Chalmers induction heating. Chances are this most advanced method of applying heat will boost your production, decrease costs and improve quality just as it has in hundreds of applications. For complete information, see your A-C representative or write Allis-Chalmers, Industrial Equipment Division, Milwaukee 1, Wisconsin.

Jambor uses a 20-kv Allis-Chalmers induction heater. The work coil and quenching ring were specially designed for the specific job by Allis-Chalmers.

A-C ALLIS-CHALMERS

ALLIS-CHALMERS

A-5432



Use WELDED STEEL for Greater Strength with Less Weight!

The 100-ton weldment illustrated above is the base unit of a housing for a 300,000 kw Steam Turbine. It is another example of Mahon craftsmanship and Mahon's ability to serve you. This heavy weldment, and those appearing at the left, are typical of the thousands of Steel-Weld Fabricated Parts and Assemblies produced by Mahon each year for manufacturers of processing machinery, machine tools, and other types of heavy mechanical equipment. If you are not now taking full advantage of the economies offered by welded steel components in your product, you should give the matter serious thought. In the design of almost any type of heavy machinery, or mechanical engineering project, there are parts and sub-assemblies that can be produced more economically, more satisfactorily, and in less time, in welded steel. In weldments you get greater strength with less weight—plus the additional advantages of greater rigidity and 100% predictability. When you consider weldments, you will want to discuss your requirements with Mahon engineers, because, in the Mahon organization you will find a unique source for weldments or welded steel in any form . . . a fully responsible source with complete facilities for design engineering, fabricating, machining and assembling . . . a source where design skill is backed up by craftsmanship which assures you a finer appearing product embodying every advantage of Steel-Weld Fabrication. See Sweet's Product Design File for information, or have a Mahon sales engineer call at your convenience.

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WHAT'S NEW AT BRISTOL...

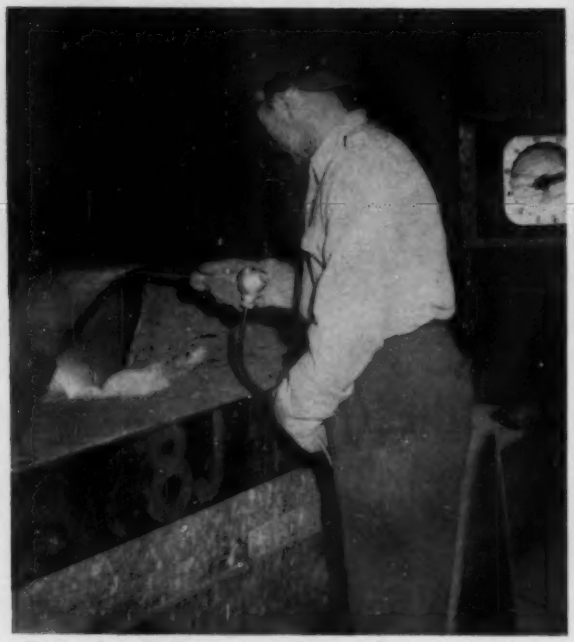


Photo courtesy General Thomas J. Rodman Laboratory, Watertown (Mass.) Arsenal.

NEW!

Immersion thermocouple for molten metals measures to 3200 F

The new Bristol portable immersion-type thermocouple is designed for direct measurements in melts of both ferrous and non-ferrous metals. Simplicity and operating economy are its key features.

Rugged tubes give economy. Latest result of Bristol's continuous development program in instruments and accessories for pyrometry, the new thermocouple's durable protection tube can take up to 14 dips in molten steel at 2700 F to 3200 F. Metals of lower melting temperatures such as brass and aluminum will give far longer life. What's more, replacement of the protection tube, plus reasonable care, allows re-use of the platinum sensing element—most expensive part of the unit.

Standard and "high-speed" models. The standard model of the new thermocouple—full response 30-45 seconds—features a Bristol metal-ceramic (LT-1) secondary protection tube. A special "high-speed" model—response 15-20 seconds—has a single quartz protection tube with quick-change thumbscrew, designed for easy replacement.

STOCK PARTS CUT COSTS, SPEED SERVICE

All parts in the new molten metal thermocouple are stock parts—a product of Bristol's careful design and advanced manufacturing methods. Result: lower first cost due to production economies and faster delivery on replacement parts.

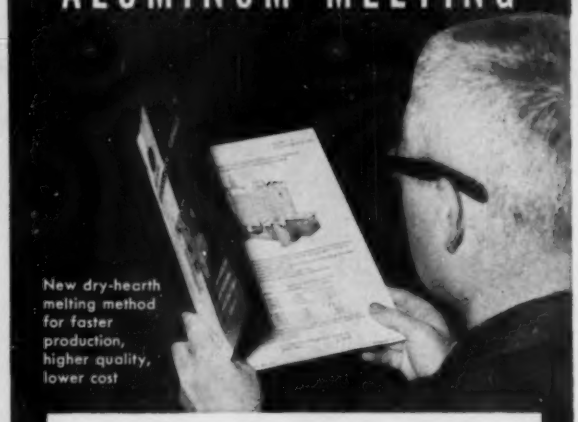
Write today for complete data on this outstanding Bristol contribution to instrumentation in metallurgy. The Bristol Company, 155 Bristol Road, Waterbury 20, Connecticut.

7.1

BRISTOL *TRAIL-BLAZERS IN PROCESS AUTOMATION*

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

NEW WAY TO COUNTER COST SPIRALS IN ALUMINUM MELTING



New dry-hearth melting method for faster production, higher quality, lower cost

Learn how to eliminate overheating, scrap . . . save on fuel through the most important new furnace in over 40 years! The new Eclipse dry-hearth reverberatory furnace has the melting and holding chambers completely separated for constant pouring temperatures and improved production control . . . continuous production-line melting of high-quality metals at a low cost! Fact-filled bulletins illustrate how you introduce *numerous* efficiency advantages into die-casting, permanent- mold, or sand-casting work. Top-fired and mechanically tilting, as well as single- or double-side and end dip-out models described. Use this convenient check box to obtain free copies: ☐

New bulletin on crucible and dry-hearth furnaces—latest model Eclipse pot and crucible furnaces, with gas, oil, or combination gas-oil firing, and dry-hearth furnaces are clearly pictured and described. To obtain your free copy of this new bulletin on efficient, economical quality melting of nonferrous metals simply make a check mark in this box: ☐

New bulletin on Eclipse Heat-Treat Furnaces—11 latest models shown and described . . . air-draw types, salt pots, pit-type, controlled atmosphere, box furnaces, and others. Wide range of sizes and choice of designs. Check this box for your free copy: ☐

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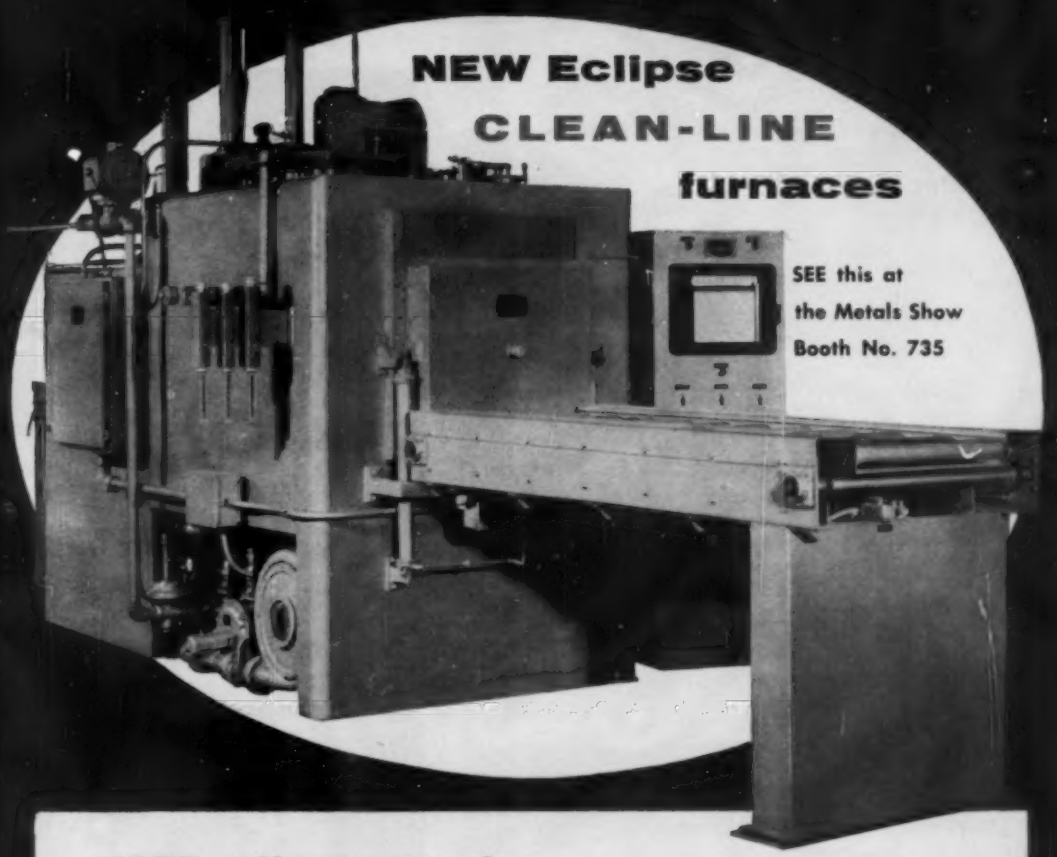
Brings more uniformity to heat-treating



MORE uniform quench

MORE uniform heat

MORE uniform case depth

All these "plusses" are yours with the new Eclipse Clean-Line furnace because: (1) atmosphere and temperature are distributed with complete uniformity during heating — there's no stratification — and (2) even tightly packed loads of the smallest parts are quenched uniformly in the oil jet-agitated tank served by the high-capacity pump. The Clean-Line furnace, rated to heat-treat 400 lb of work in one hour, and with quench capacity for 700 lb per load, is designed for fully automatic clean hardening, carbonitriding, carburizing, carbon restoring, or annealing. Standard Clean-Line furnaces are designed for operation at temperatures up to 1850° F.

Complete control of all heat-treat operations is right at your fingertips. You can select an air or oil quench, for example, just by flicking a switch on the control panel. Heating cycle, high oil pump circulation, and quenching cycle for a particular workpiece can all be controlled precisely and automatically by three separate timers on the control panel. All these features add up to better quality — every piece in every batch.

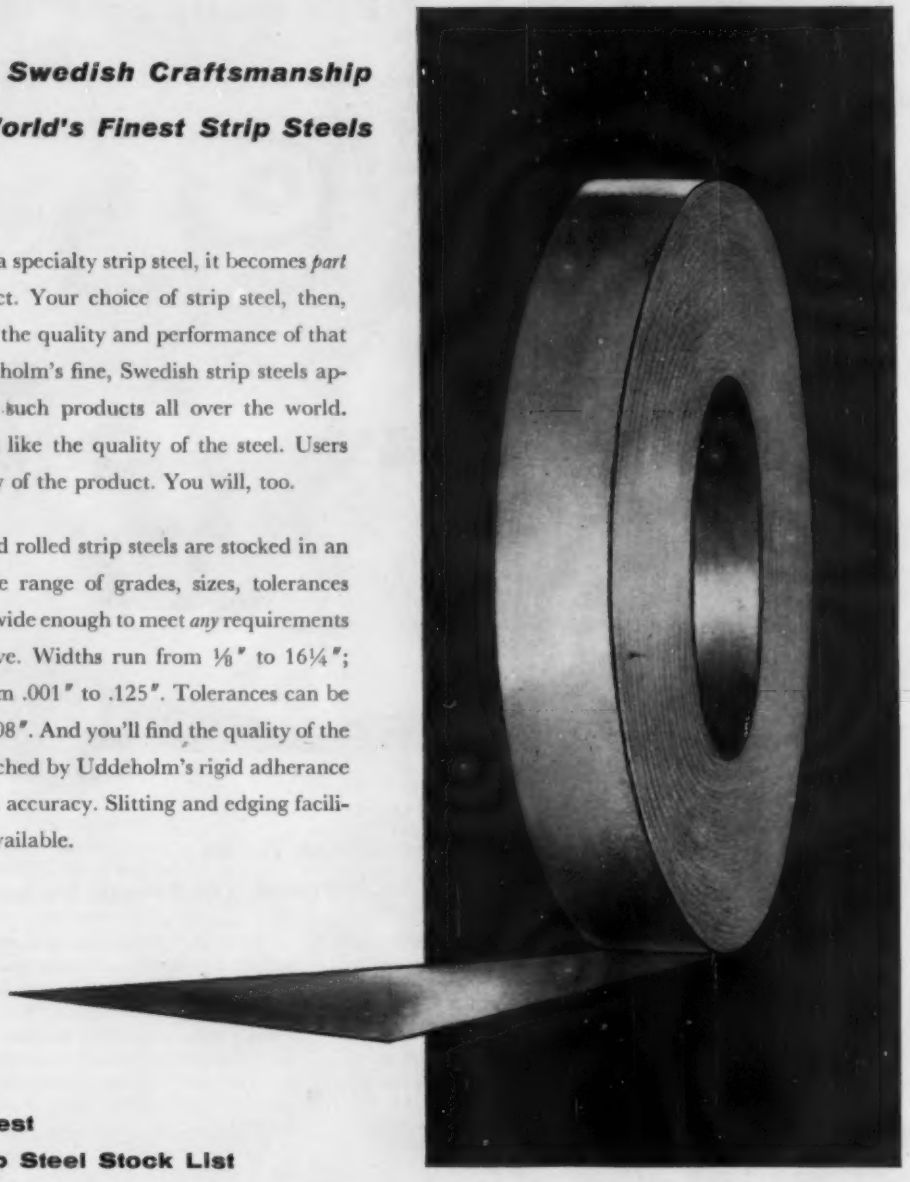
WRITE for bulletin and data sheets describing the Clean-Line system that includes endothermic generators, automatic washers, and tempering units.

Eclipse®

UDDEHOLM Strip Steel Quality Belongs In Your Product

Traditional Swedish Craftsmanship

Produces World's Finest Strip Steels



When you use a specialty strip steel, it becomes *part* of your product. Your choice of strip steel, then, will determine the quality and performance of that product. Uddeholm's fine, Swedish strip steels appear in many such products all over the world. Manufacturers like the quality of the steel. Users like the quality of the product. You will, too.

Uddeholm cold rolled strip steels are stocked in an extremely wide range of grades, sizes, tolerances and finishes—wide enough to meet *any* requirements you might have. Widths run from ⅛″ to 16¼″; thicknesses from .001″ to .125″. Tolerances can be held to ±.00008″. And you'll find the quality of the steel itself matched by Uddeholm's rigid adherance to dimensional accuracy. Slitting and edging facilities are also available.

Write for latest
Strip Steel Stock List

UHB

UDDEHOLM COMPANY OF AMERICA, INC.

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Specialty Strip Steels

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Cleveland: 4540 East 71st Street, DIamond 1-1110
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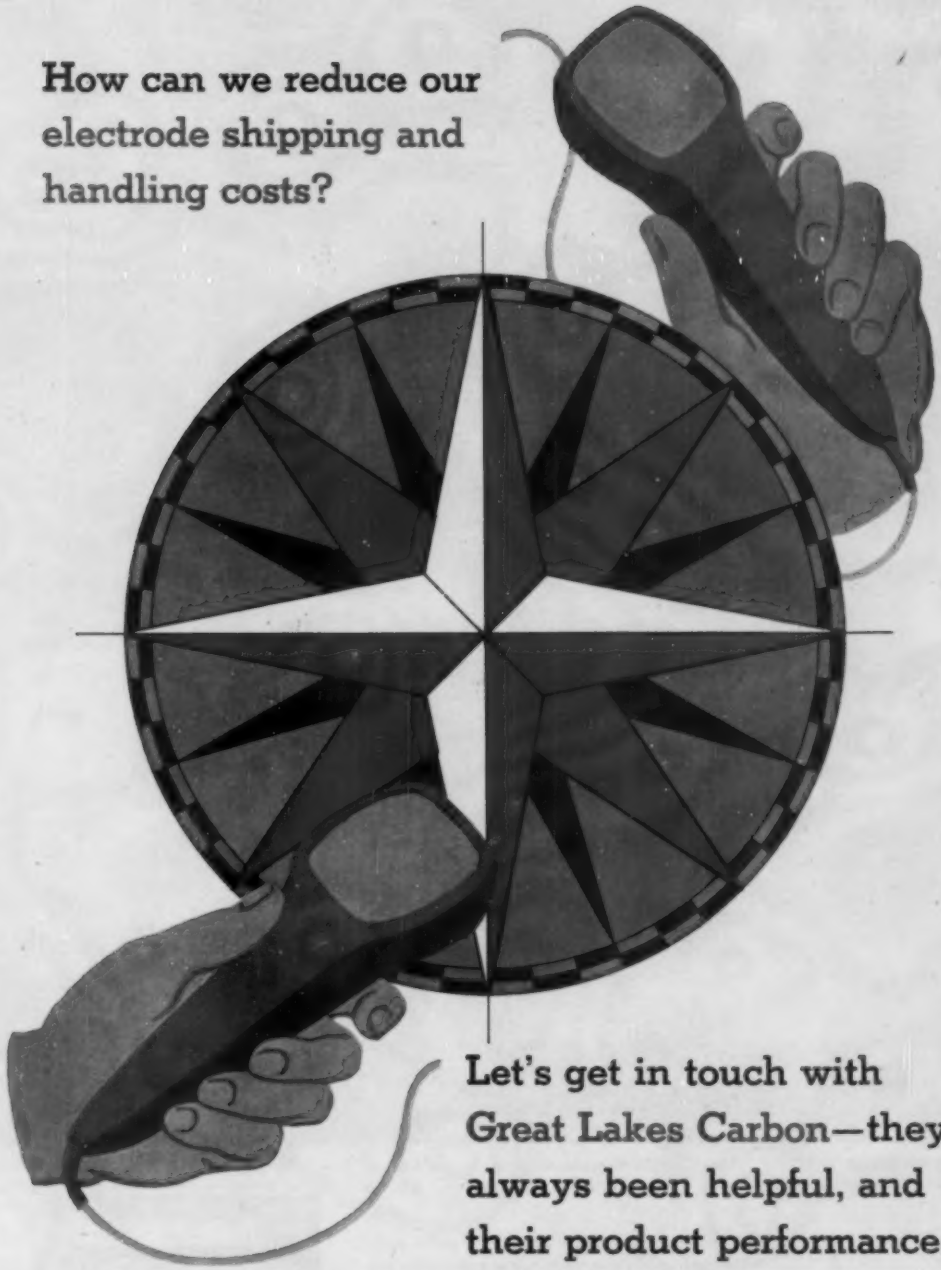
How can we reduce our electrode shipping and handling costs?



Let's get in touch with Great Lakes Carbon—they've always been helpful, and their product performance is outstanding!

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GREAT LAKES CARBON CORPORATION

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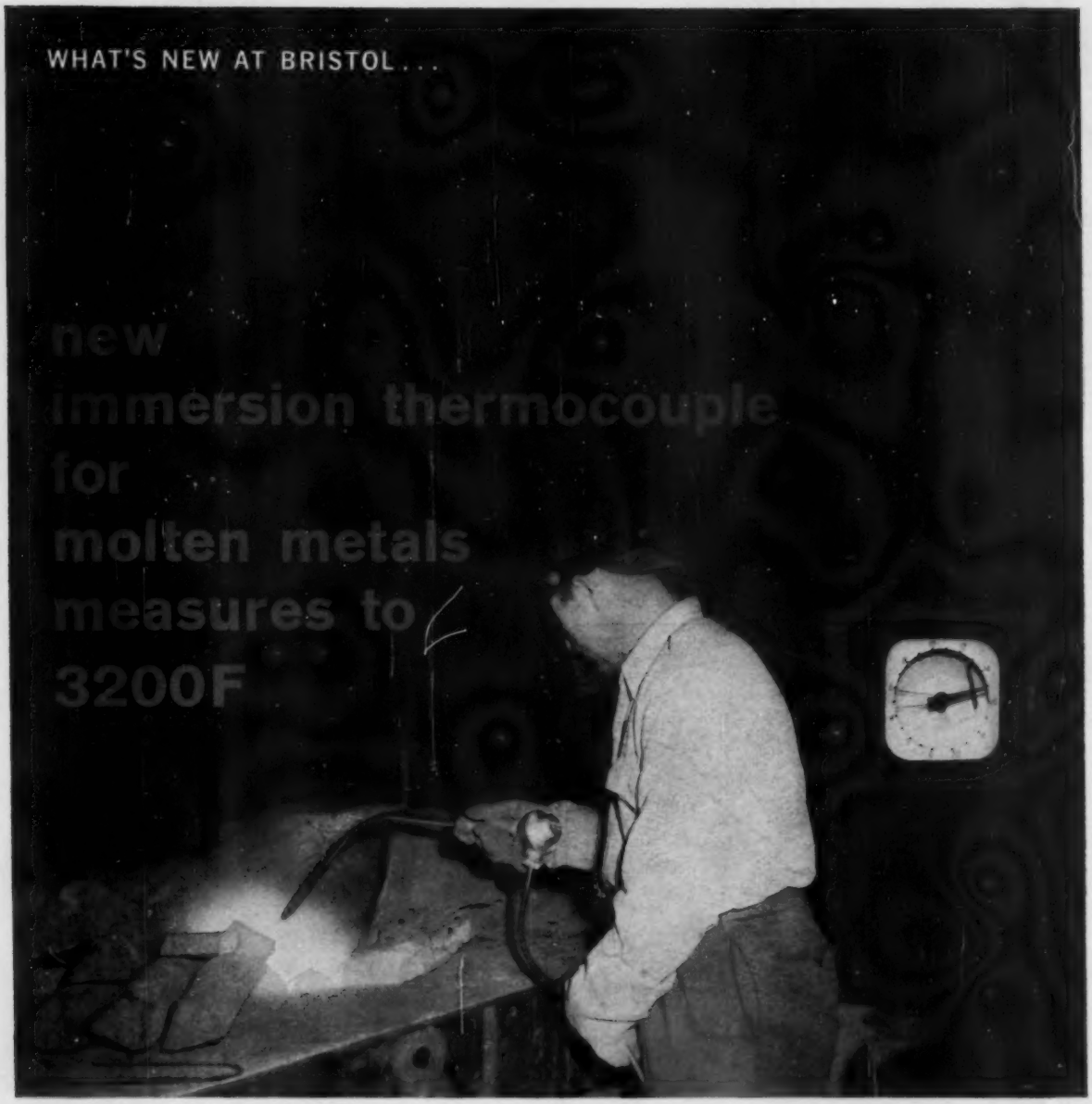


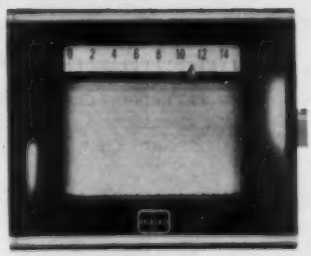
NEW BRISTOL IMMERSION THERMOCOUPLE makes direct readings in melts of ferrous or non-ferrous metals, records on round-chart Bristol Dynamaster instrument (right).

This new Bristol immersion-type thermocouple can take up to 14 dips in molten steel at 2700 F to 3200 F. With brass, aluminum and other metals of lower melting point, it has far longer life.

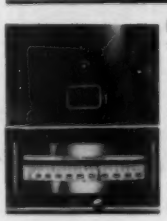
Simplicity, operating economy result from the new thermocouple's rugged, easily replaceable protection tubes. With reasonable care, they allow reuse of the expensive platinum sensing element.

This new Bristol immersion thermocouple is typical of recent outstanding Bristol developments in electronic pyrometry. Bristol's giant strides in automatic temperature control *are making instrument systems obsolete which were designed new only a few years ago.* Find out about these developments, before you buy any other instrument for furnace or oven. Write The Bristol Company, 106 Bristol Road, Waterbury 20, Conn. 7.23

*T. M. Reg. U. S. Pat. Off.



Dynamaster* Electronic Pyrometer with strip chart.



Free-Vane* Electronic Pyrometer Controller.

ELECTRONIC INSTRUMENTS BY BRISTOL

BRISTOL TRAIL-BLAZERS IN PROCESS AUTOMATION

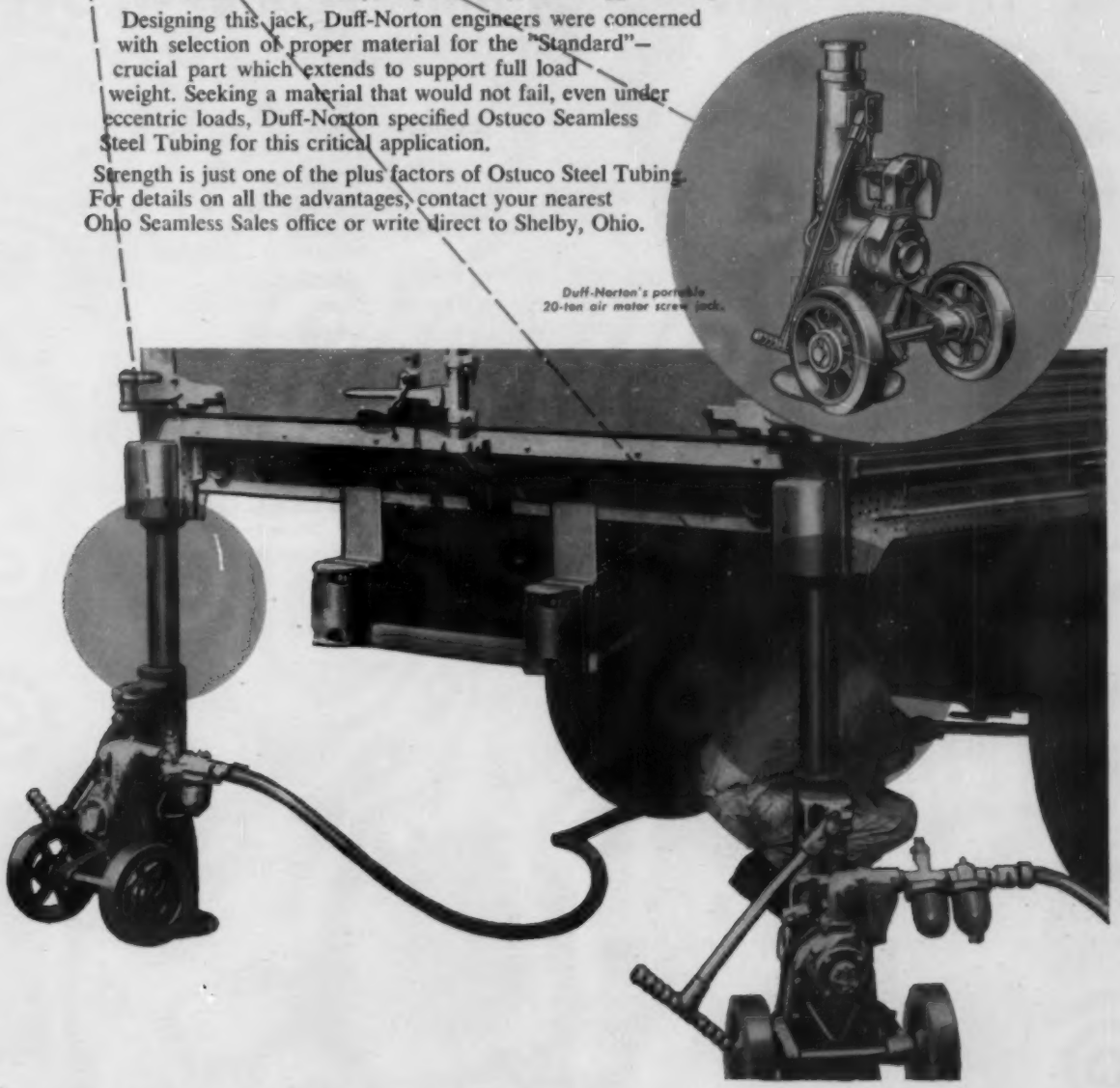
AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

STRENGTH PROBLEM SOLVED with Ostuco Steel Tubing

Duff-Norton Company, Pittsburgh, manufactures a portable 20-ton air motor screw jack now finding wide acceptance as a maintenance tool by the trucking industry because of its versatility, dependability, and rugged strength.

Designing this jack, Duff-Norton engineers were concerned with selection of proper material for the "Standard"—crucial part which extends to support full load weight. Seeking a material that would not fail, even under eccentric loads, Duff-Norton specified Ostuco Seamless Steel Tubing for this critical application.

Strength is just one of the plus factors of Ostuco Steel Tubing. For details on all the advantages, contact your nearest Ohio Seamless Sales office or write direct to Shelby, Ohio.



Duff-Norton's portable 20-ton air motor screw jack.

OSTUCO SHELBY OHIO

OSTUCO TUBING

MANUFACTURED IN

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EXCLUSIVELY BY

OHIO SEAMLESS TUBE DIVISION

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SHELBY, OHIO • Birthplace of the Seamless Steel Tube Industry in America

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Modern Steelmaking

How Exhaustive Tests Guard the High Quality of Stainless Steel at J&L

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This metallographic microscope is used to inspect for cleanliness and proper structure.

A Rockwell Hardness Tester is used to measure the hardness of a specimen after heat treatment.

Complete heat treating facilities are available for use in preparing metal samples for testing.

Tensile testing determines ultimate tensile strength, proportional limit, yield strength, elongation and reduction of area.

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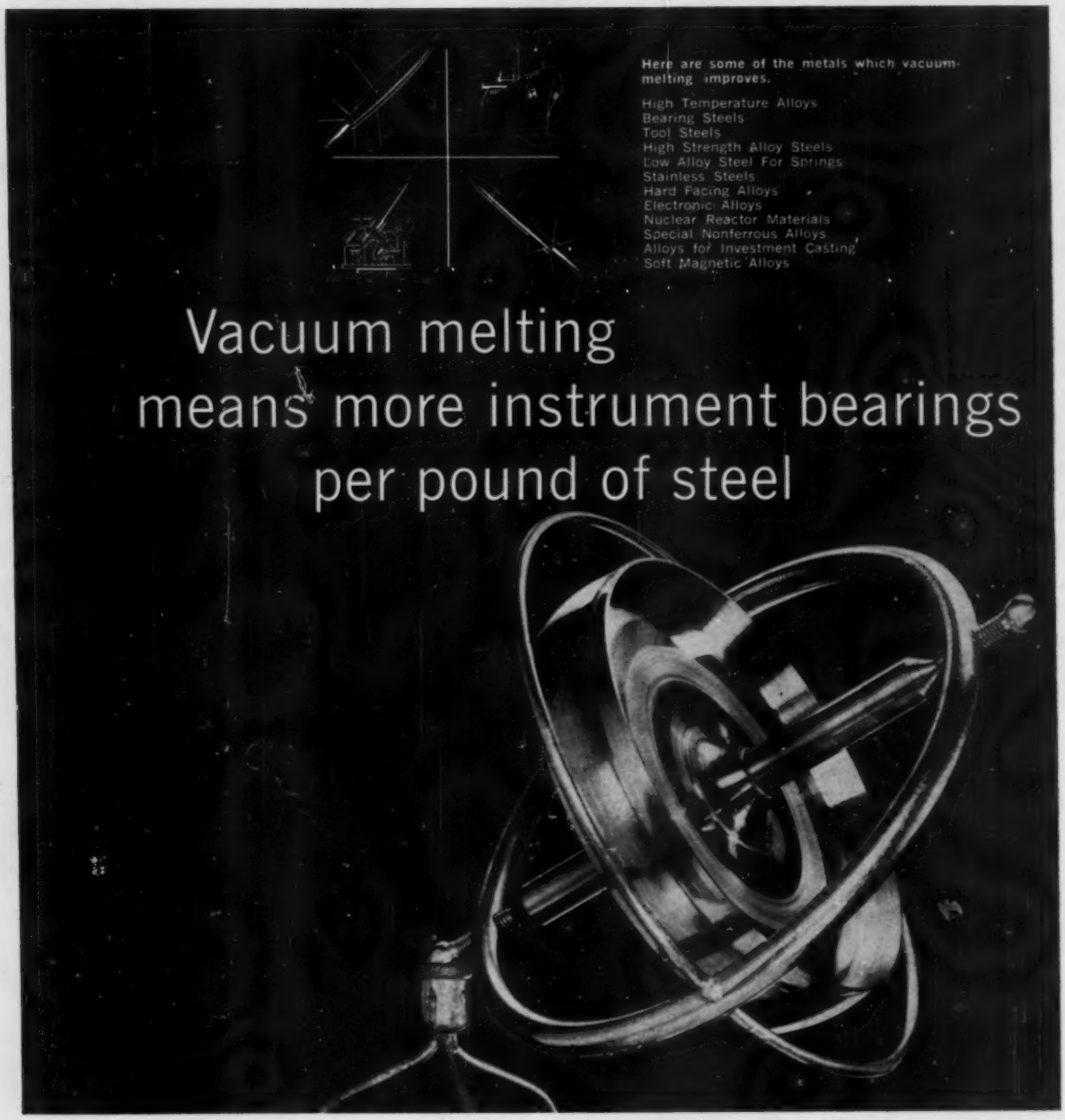

Gyros are the heart of many modern navigation and fire-direction devices. The ball bearings used in these gyros are expensive to manufacture, for, with air-melted alloys, rejects average 15%. *But with vacuum-melted alloys, rejects of finished balls have dropped to less than one percent.* Here's why:

Surface finish is better because vacuum-melting reduces inclusions to the lowest level commercially possible . . . properties of the steel are more uniform in all directions and from heat to heat . . . fatigue, impact and ductility are substantially improved. Specifically, 52100, 51100, 440-C and similar grades are being used in production quantities for the most critical bearing applications.

Vacuum Metals Corporation, Division of Crucible Steel Company of America, is the first and largest producer of vacuum-induction melted metals. VMC produces a wider variety of alloys than any other company. And it is now doubling its capacity to meet increasing demand from industry. A VMC engineer will be glad to work with you on metals problems which vacuum-melted metals may solve. Please write, giving as much data as possible, to Vacuum Metals Corporation, Division of Crucible Steel Company of America, P. O. Box 977, Syracuse 1, N. Y.

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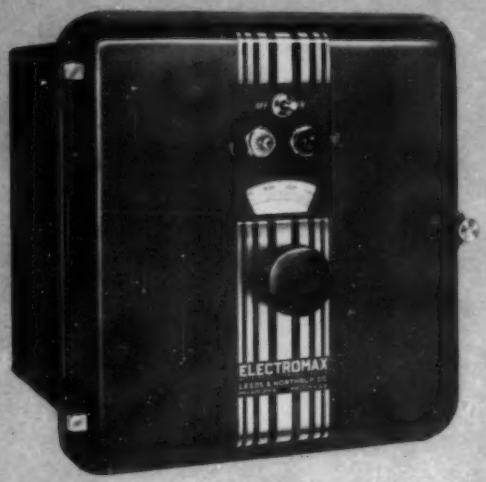
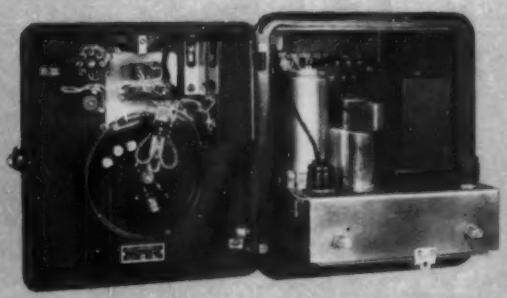
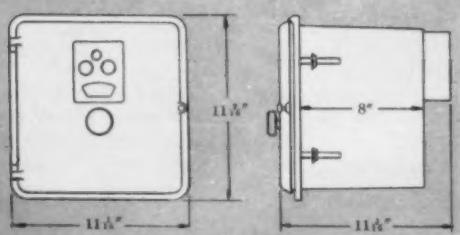




Design simplicity minimizes maintenance; sturdy components resist normal shock and vibration. Precisely calibrated slidewire and circuit resistors hold stability. For easy servicing, amplifier slides out of case; standard vacuum tubes are used . . . their replacement requires no special selection.



Compact Electromax controller mounts flush in panel. Leads are brought to terminal board located on back of case. Net weight about 27 pounds.

Thermocouple Electromax® Controller for temperatures up to 3200 F

- ***0.3% LIMIT OF ERROR***
- ***10 μV* CONTROL DEAD BAND***
- ***CONTINUOUS STANDARDIZATION***
- ***4-WEEK DELIVERY***

**0.5 F for base metal thermocouples; approximately 1.5 F for platinum thermocouples.*

Combining all the accuracy and reliability of a modified d-c potentiometer with a drift-free amplifier detector, this new Electromax signalling controller provides low-cost electronic two-position control where a record or continuous indication is not required. It's ideal for many electric and fuel-fired furnaces, ovens, plastic extruding machines, and some types of chemical processing units. Other uses include zone control on continuous ovens and kilns, and excess (overheat) temperature cutout control.

This compact signalling controller has only two moving parts—a plug-in relay and converter (chopper). These, together with simple circuitry and liberal use of plug-in components (including a plug-in amplifier), minimize maintenance and reduce initial cost. To speed start up of your process, Electromax is delivered four weeks after receipt of your order.

Other standard features include both thermocouple and amplifier fail-safe, and automatic reference junction compensation. Amber and red signal lights indicate whether process temperature is above or below set point.

For additional information on the thermocouple Electromax, call your nearest L&N office or write 4927 Stenton Ave., Philadelphia 44, Pa. Ask for Preliminary Data Sheet ND47-33(1).

LEEDS Instruments **NORTHRUP** Automatic Controls • Furnaces

Columbia Tool Steels for 1957-58
with A.I.S.I. Identification and Type Classification of Tool Steels

GRADE	Identifying Elements, in Per Cent										
	Type	C	Mn	Si	Cr	Ni	V	W	Mo	Co	Cb
WATER HARDENING TOOL STEELS — TYPE SYMBOL W											
Columbia SPECIAL	W1	.60/1.40	—	—	—	—	—	—	—	—	—
Columbia EXTRA	W1	.60/1.40	—	—	—	—	—	—	—	—	—
EXTRA HEADERDIE	W1	.60/1.40	—	—	—	—	—	—	—	—	—
Columbia STANDARD	W1	.60/1.40	—	—	—	—	—	—	—	—	—
Columbia ELECTREX	W1	.60/1.40	—	—	—	—	—	—	—	—	—
VANADIUM EXTRA	W2	.60/1.40	—	—	—	—	.25	—	—	—	—
VANADIUM STANDARD	W2	.60/1.40	—	—	—	—	.25	—	—	—	—
	W3	1.00	—	—	—	—	.50	—	—	—	—
	W4	.60/1.40	—	—	.25	—	—	—	—	—	—
WATERDIE EXTRA	W5	1.10	—	—	.50	—	—	—	—	—	—
WATERDIE STANDARD	W5	1.10	—	—	.50	—	—	—	—	—	—
	W6	1.00	—	—	.25	—	.25	—	—	—	—
	W7	1.00	—	—	.50	—	.20	—	—	—	—
SHOCK RESISTING TOOL STEELS—TYPE SYMBOL S											
BUSTER	S1	.50	—	—	1.50	—	—	2.50	—	—	—
	S2	.50	—	1.00	—	—	—	—	.50	—	—
	S3	.50	—	—	.75	—	—	1.00	—	—	—
	S4	.55	.80	2.00	—	—	—	—	—	—	—
CEC SMOOTHCUT†	S5	.55	.80	2.00	—	—	—	—	.40	—	—

†With smooth cutting free machining additives

First of a Series of Six Charts Covering A.I.S.I. Tool Steel Type Classifications

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COLUMBIA TOOL STEELS

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MOLY NEWS

CLIMAX MOLYBDENUM COMPANY, 500 FIFTH AVENUE, NEW YORK 36, N. Y.

Ultra-Strength Steels Boost Tensile Strengths to 300,000 psi.

Ten years ago, engineers considered 180,000-psi tensile strength in steels the maximum they could use safely.

Today, alloy steels with minimum strengths of 220,000 to 300,000 psi are being used commercially. These ultra-strength steels have the ductility and toughness needed for structural applications. At tensile strengths above 220,000 psi, they show more strength per pound of product than high-strength aluminum alloys. And at 260,000 psi, they are approximately 15% lighter than aluminum alloy products of the same strength.

Molybdenum is an essential element in almost all of these steels.

How are the higher strengths and strength/weight ratios of these steels being used? Until recently, they've been utilized almost exclusively in aircraft components, such as landing gear. Now, however, they're being considered wherever weight and space savings compensate for higher fabrication costs . . . as, for example, in equipment that must be moved (portable tools); gears, pulleys, belts, liners; heavy machinery operating at high stresses; machinery where inertia is a design factor; materials-handling equipment, such as cranes; and transportation equipment.

Like to know more about ultra-strength steels and their properties, and the names of manufacturers? For our free booklet, circle #1 on the coupon.

Bulletin Shows How to Get Heat Resistance in Cast Iron

In cast iron, heat resistance can mean different things: resistance to growth, to heat checking, to scaling, or to deformation under load at high temperatures.

"Why Moly Iron? #5" contains a chart showing the specific kinds of heat resistance needed by parts such as brake drums, melting pots, piston rings and so on. This chart also lists the best type of iron to use and the proper alloy additions. A number of detailed case histories document this useful bulletin.

For a free copy of "Why Moly Iron? #5" circle #2.

New Coatings May Solve Moly's Oxidation Problem

The most important obstacle to using molybdenum at high temperatures is being overcome. Oxidation is the problem; at temperatures over 1000F, molybdenum oxidizes rapidly.

Newly developed coatings offer molybdenum the needed protection. Three types are promising:

1. Electro-deposited chromium and nickel layers which protect molybdenum to 2000F.

2. Sprayed coatings of aluminum-chromium-silicon alloys, and nickel-boron alloys, which have proved effective at 2000-2400F.

3. Ceramic and molybdenum disilicide coatings which hold promise of protecting molybdenum from oxidation at even higher temperatures.

Digested from "Protecting Molybdenum at High Temperatures" by Julius Harwood, Materials & Methods. For reprint of entire article, circle #3.

Booklet Deals with Molybdenum Joining Techniques

Recent progress in joining molybdenum, and suitable means for protecting it from oxidation, are opening up new uses for molybdenum and its alloys in structural components for high-temperature service.

"A New Look at Joining Molybdenum" by R. R. Freeman and J. Z. Briggs, both of Climax, analyzes the factors involved in joining moly and discusses the methods available.

For the free booklet, circle #4.

List of Moly Literature Now Available

Copies of more than 30 recent pieces of technical literature on molybdenum are available from Climax Molybdenum Company. *For a free list of these, including titles, authors, sources and 25-30 word summaries, just circle #5.*

Steels for Power-Plant, Refinery Equipment at 900-1100F

Designers of power-plant and refinery equipment who need to select steels for applications at 900 to 1100F will be interested in a copy of "Chromium-Molybdenum and Chromium-Molybdenum Vanadium Steels for power-plant and refinery service up to 1100F."

This paper, presented at the ASME annual meeting by George V. Smith, Bard Professor, Cornell University, appraises literature on the subject and draws some new, objective conclusions.

For a free reprint, circle #6.

New Climax Alloy Proves Unusually Wear Resistant

These liner castings, made of Climax 321, proved highly resistant to wear in our ball mill discharge launders. Severe wear normally occurs in this operation as a result of erosion from the coarse pulp flowing out of the ball mill discharge.

If you need a highly wear-resistant material, you may be interested in our new Climax 321 Alloy. It's a hard, martensitic type of white iron containing nickel, chromium and molybdenum in proportions that are well balanced, both metallurgically and economically.

We've been using 321 Alloy in our own mining operations with exceptional results. Comparative tests in ball mill liners and grinding balls proved its excellent wear-resisting properties.

Because this alloy is relatively new, service results in other applications are not yet available. However, our laboratory studies and data indicate it should prove suitable for the general run of abrasion-resistant castings of the martensitic white iron type—such as wear shoes, sand and dredge pump wearing parts, pug mill knives, mixer liners, etc.

Climax 321 can be melted in a cupola or electric furnace and cast in either sand or permanent (chill) molds. It has a normal hardness range of 55 to 62 Rockwell "C".

Composition: Carbon 3.30-3.60%; Silicon 0.30-0.60; Manganese 0.50-0.80; Nickel 2.75-3.25; Chromium 1.75-2.25; Molybdenum 0.70-1.10; Sulphur 0.15 max.; Phosphorus 0.30 max. *For data sheet, circle #7.*

Climax Molybdenum Company, Dept. 5
500 Fifth Avenue, New York 36, N. Y.

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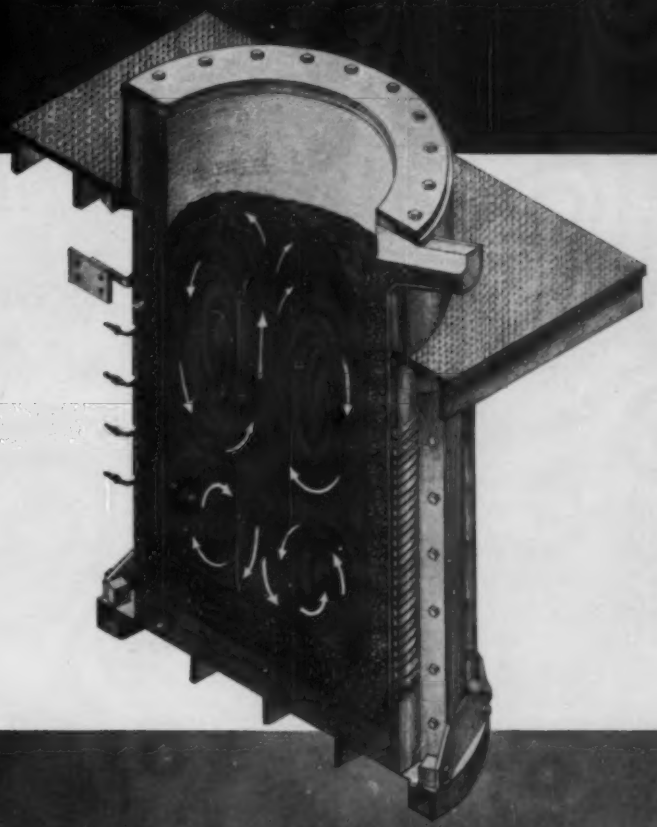

*The Metal Show
International
Amphitheatre
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A cylindrical induction coil supplied with ordinary 60 cycle current induces heat and vigorous electromagnetic stirring in the molten metal charge. Integrated electric controls regulate power, maintain high power factor automatically. Monolithic refractory linings are made by ramming against the sturdy water-cooled coil held in a rigid frame of magnetic and structural steel.

This new principle was perfected in Europe over the last seven years. Over 100 Junker furnaces are now in use. AJAX-JUNKER designs are based on latest experience, using American components and practices throughout.

Outstanding results are proven in these fields:

DUCTILE AND ALLOY IRON CASTINGS
RECOVERY OF IRON TURNINGS
RECOVERY OF ALUMINUM SCRAP

Available sizes range from 2 to 10 tons, with normal melting cycles from 2 to 4 hours. Power ratings are 200 kw through 1500 kw.

IF YOU ARE UNABLE TO ATTEND THE SHOW SEND FOR BULLETIN R-52

AJAX USA

60 CYCLE INDUCTION MELTING

ENGINEERING CORPORATION

TRENTON 7, NEW JERSEY

Associated Companies: Ajax Electrothermic Corporation Ajax Electric Company

KEY TO FORGINGS ILLUSTRATED

1. Jet Engine Pad — Titanium — 11 lbs. —17 inches.
2. Jet Engine Vane — Titanium — 27 lbs. — 15 inches.
3. Aircraft Support — Aluminum — 20 lbs. — 49 inches.
4. Aircraft Fitting — Aluminum — 282 lbs. — 86 inches.
5. Aircraft Landing Gear — Aluminum 284 lbs. — 47 inches.
6. Missile Ring Splice — Aluminum — 54 lbs. — 20 inches.
7. Aircraft Spar Frame — Aluminum — 434 lbs. — 142 inches.
8. Missile Fin — Aluminum — 8 lbs. — 30 inches.

Faster and faster, higher and higher — greater stresses, increased temperatures — all leading to continually increasing dependence on forgings — and in the forging field there is no substitute for Wyman-Gordon quality, experience and know-how.

WYMAN-GORDON COMPANY

Established 1883

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Crucible offers you precision-rolled stainless strip—in all standard grades —that is unsurpassed in uniform quality and finish. And when you buy from Crucible, you get these qualities consistently in coil after coil, no matter how many you order. »»»» *Remember:* Crucible's operations are fully integrated from raw material to delivery to you—a fact that assures you of high quality and prompt, dependable service. *Crucible Steel Company of America, The Oliver Building, Mellon Square, Pittsburgh 22, Pa.*

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Used Exclusively

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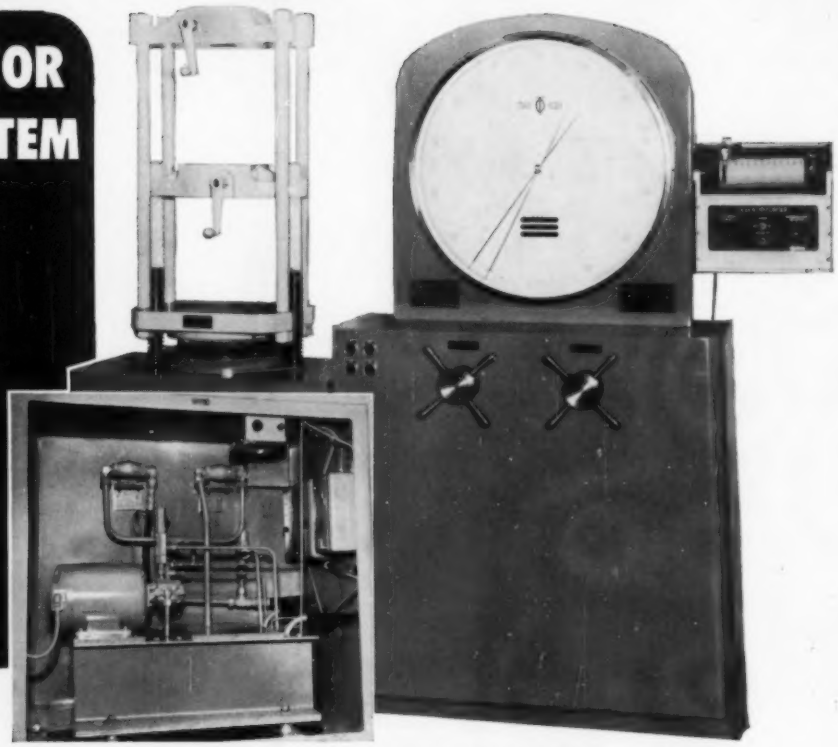


INSET SHOWS PORTION OF THE REVOLUTIONARY NEW DUAL PRESSURE LOADING SYSTEM USED IN OLSEN SUPER "L"S, SUCH AS THE 60,000 LB. CAPACITY MACHINE ABOVE.

METAL SHOW
BOOTH 1346

Keeping pace with the revolutionary Selectrange Indicating System, the hydraulic loading system used in all Tinius Olsen Super "L" testing machines has been completely modernized. Uniform load application is assured by the new, exclusive Olsen stabilized piston design. This includes a dual pressure pump which provides positive piston lubrication under all loading conditions. The oil reservoir is shock mounted and flexible connections are used so that no vibration or pulsation is transferred to the indicating system.

Loads are indicated with unmatched speed and accuracy on the large color coded Selectrange dial. With three separate ranges to choose from, loads as low as 1/50 capacity can equal full scale range for accurate load determination—and the range can be changed during test with a flip of the Selectrange switch. When a load cell is used, loads as low as 200 grams can represent full scale.

Stress-strain curves, are plotted automatically when the Olsen Model 51 electronic recorder is used. To assure accurate curves on specimens of all types, Olsen offers the widest selection of strain instrumentation available.

For flexibility, accuracy plus unequalled ease of operation and low cost, the Tinius Olsen Super "L" is your best universal or compression testing machine buy.

Get full details. Write today for Bulletin 47.

Trademark
Reg. U.S. Pat. Off.

TINIUS OLSEN
TESTING MACHINE COMPANY

2030 EASTON ROAD • WILLOW GROVE, PA.

Testing and Balancing Machines

AT MASSACHUSETTS STEEL TREATING CORPORATION . . .

NEW General Electric Induction Heater Brazes and Hardens up to 3 Tons of Job-lot Parts Every Day

The new General Electric induction heating equipment used at Massachusetts Steel Treating Corporation, Worchester, Massachusetts, quickly won the praise of Mr. Harry E. Boorky, their manager of manufacturing.

FAST, HIGH QUALITY: Says Mr. Boorky, "The unit gives us automatically controlled heating and quenching cycles for treatment of the entire length or of any portion of the piece in only one pass."

BETTER CUSTOMER SERVICE: "In addition, this new G-E heater gives us the advantage of quick-set-up changes required of the high-quality job-lot production we do for our customers.

"Because induction heating can be carefully controlled to the exact point where needed and because it is extremely fast, the parts which we treat are virtually free of troublesome scale—so customers are relieved of many cleaning operations. They also save on press or hammer maintenance and die life is increased."

FOR YOUR APPLICATION: General Electric electronic induction heaters are available in four ratings—7½-, 15-, 25-, and 40-kw, with a choice of four different models in each rating. These four models provide various control combinations, so you can buy the one induction heater which best matches your production pattern from the standpoint of both rating and control. You don't buy wasted capacity.

HEAT TREATING PROBLEMS? Just call your local General Electric Apparatus Sales office, or send the coupon at right.

GET MORE INFORMATION

GENERAL ELECTRIC COMPANY
SECTION D722-7
SCHENECTADY 5, NEW YORK

Please send me a copy of Bulletin GEA-6388.

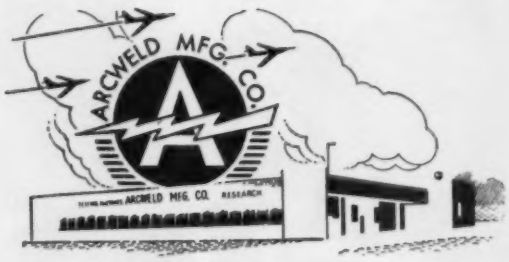
NAME.....

COMPANY.....

ADDRESS.....

CITY.....STATE.....

GENERAL ELECTRIC



The Arcweld Manufacturing Company extends a cordial invitation to the visitors at the 39th National Metal Exposition to visit Booth 1019 and discuss their testing problems and needs with us, and to see the following new equipment on display:

Arcweld Model "EE" Machine for either Relaxation Testing, Elevated Temperature Tensile Testing and/or Creep Testing.

Arcweld Model "G" Machine with 30,000 pound capacity.

Rapid Heating Unit for resistance heating to any desired testing temperature in seconds.

Arcweld Model "M" Machine completely re-designed but still budget priced.

Thermocouple Calibration Unit for research and laboratory use.

Arcweld Model "CE" Machine with optical creep measuring equipment.

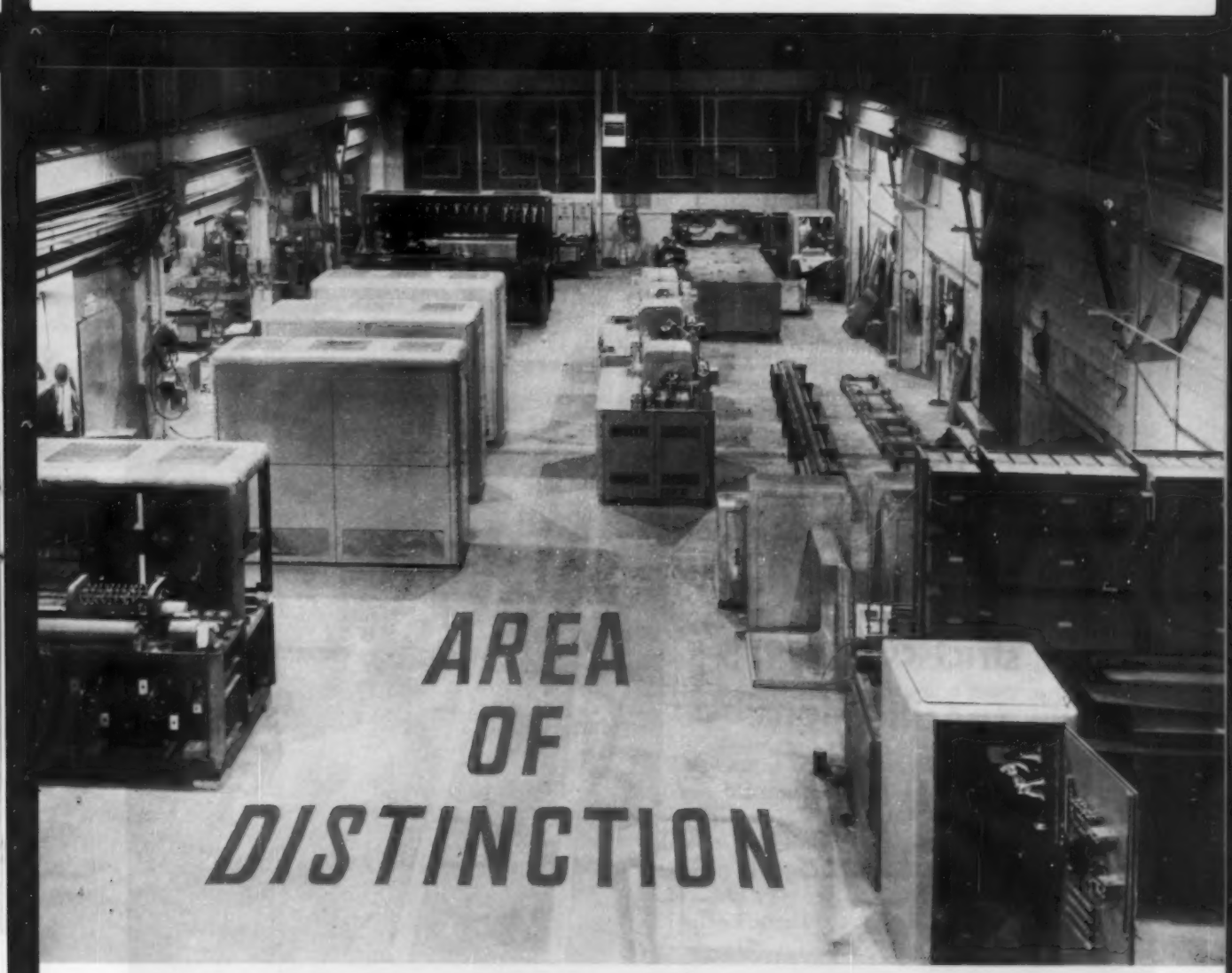
Arcweld Model "JE" Machine with completely automatic creep recording equipment.

Extensometer Systems for virtually every type of test employing optical, dial indication and fully automatic recording systems.

Manufacturers of Creep and Stress Rupture Machines, Elevated Temperature Tensile Equipment, Extensometer Systems, Atmosphere Retorts, Rapid Heating Units, and Related Equipment.

ARCWELD MANUFACTURING COMPANY

Arcweld Building • Grove City, Pa. • Phone: 1470



No other assembly floor in the world handles **INDUCTION HEATERS LIKE THESE...**

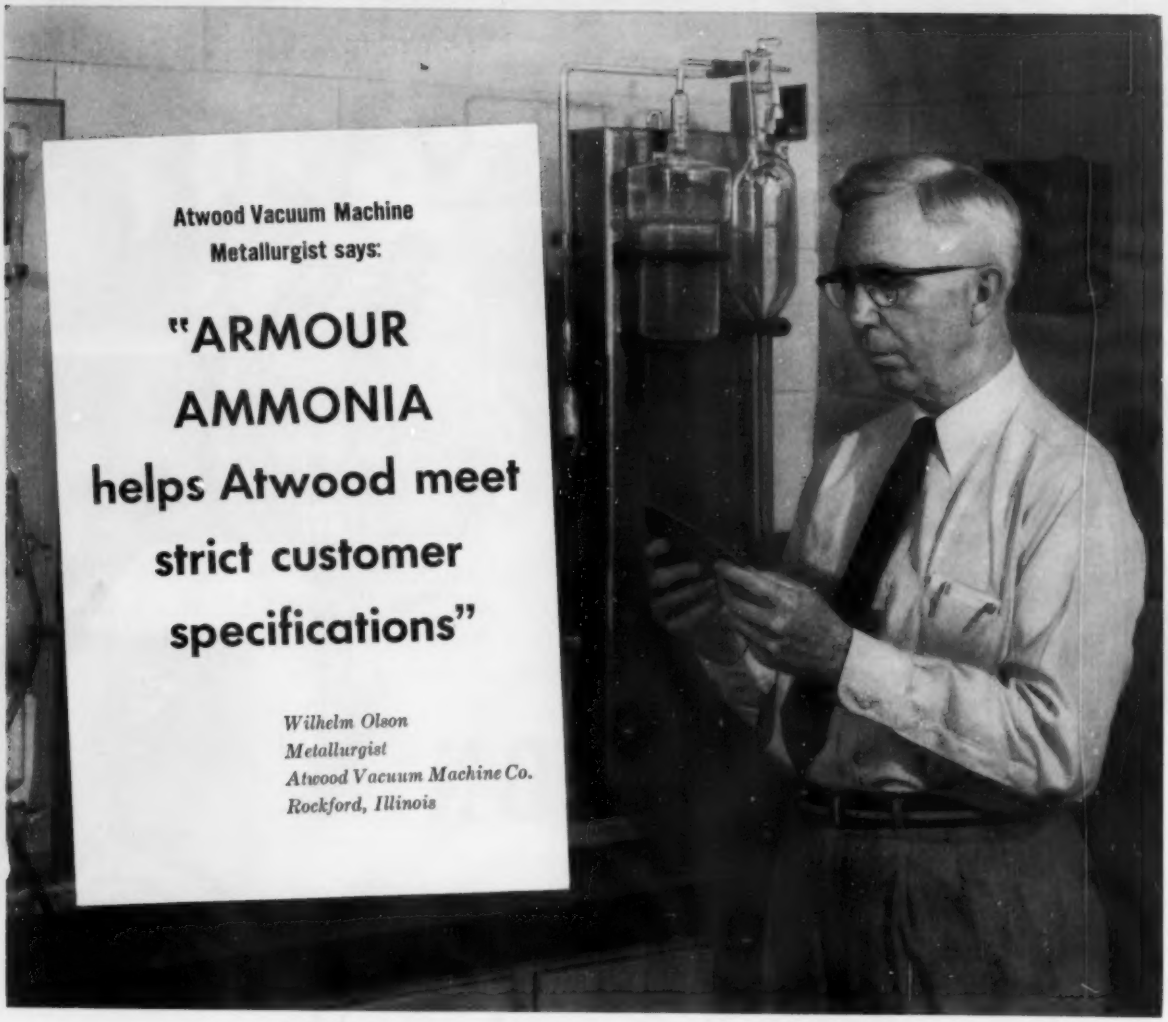
This floor has a distinction of handling a greater variety and higher quality of induction heating equipment than any other floor in the world. Every kind of induction heating unit from 60 to 450,000 cycles, including some of the largest ever built, passes through here.

Magnethermic makes a complete range of induction heating equipment. To a buyer this range offers an important advantage... **He can expect an unbiased recommendation from Magnethermic.**

Whether the need be low-frequency, dual-frequency, high-frequency or electronic equipment, your inquiry to Magnethermic receives evaluation from three viewpoints: Application — the proper frequency and design of equipment for the job. Engineering — appraisal of equipment to meet the specific needs of your product and production. Manufacturing — built for most efficient operation and matched to integrate with your production line. Net result—a more efficient induction heating installation at lower cost.

Induction Heating Equipment 60 to 450,000 cycles

MAGNETHERMIC®
CORPORATION
3990 SIMON RD. • YOUNGSTOWN 7, OHIO



"Armour technicians helped solve our ammonia problems at Benrus."

Verner R. Lundquist
Plant Engineer
Benrus Watch Company, Inc.

"At Du Mont, we cut costs with Armour Ammonia."

A. R. Dutcher
Purchasing Manager
Cathode-Ray Tube Division
Allen B. Du Mont Laboratories, Inc.

"SINCE 1916 we have produced high quality automotive body hardware. Over the years we have had to meet increasingly difficult specifications. Today they are extremely critical, and Armour Ammonia is an important factor in meeting them.

In our carbonitriding process we are given specifications that range from skin surface hardness to .030 inch case depth. Armour Ammonia's consistent high quality enables us to produce a hardness depth as low as .003 inch.

Put together a quality product, prompt delivery service, unexcelled technical assistance and you have the reasons why Atwood Vacuum buys only Armour Ammonia—and why I as a metallurgist count on it."

For 99.98% pure ammonia, backed by unexcelled technical service, call your nearest Armour sales office—or write directly to Chicago for complete information.

ARMOUR *Ammonia Division*

1355 West 31st Street • Chicago 9, Illinois

See us in Chicago at the Metal Show Booth 1768

Any similarity to a real-life company is purely intentional

How did the lathe builder get the worm to turn?

Henry Wadsworth Headstock had a dream. About a better turret lathe. It used worm gears in the drives.

He not only doodled it — he dood it. And he got a venturesome soul to try out a pilot model of his new Turnabout Lathe.

Then his troubles started to multiply — like ants at a picnic. For the worm gears conked out with a sickening regularity. There were 12 replacements in 24 weeks. (Three guesses what the big wheels thought of *that!*) Things certainly were in one heck of a mesh.

Then Henry heard of Ampco Metal, the special copper-base alloy. And he had a worm gear made out of *it*. The last we heard, the Ampco Metal gear had been running for a whole year and still showed no signs of wear.

Frankly, we're not surprised. Gear service — in fact, *any* wear application — is duck soup for Ampco Metal. It resists deformation under heavy loads and speeds — so tooth contours hold their original shape. There's no scoring, no galling — the worm has true bearing action against the worm wheel. Damping characteristics, plus fine mating properties, reduce the noise of the gear set.

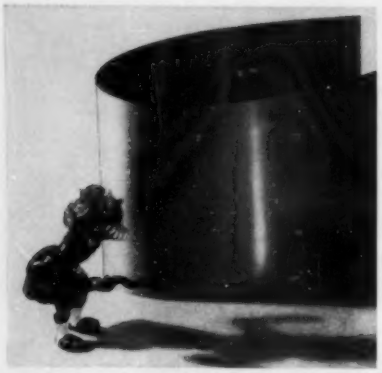
The moral is obvious: Why gamble with guesses on gear life (or other critical parts), when it's so easy to be *sure*.

If you want to know more about Ampco Metal, call in your Ampco field engineer. Write for Bulletin 33. *Ampco Metal, Inc., Dept. MP-10, Milwaukee 46, Wisconsin. (West Coast Plant: Burbank, California)*

AMPCO® METAL *The metal without an equal*

No matter which *FINISH* you like—you can buy it in

MicroRold® QUALITY STAINLESS STEEL



2D—A silvery white, but non-lustrous, surface produced by annealing and pickling cold reduced material. Steel sheets & strip in this condition are most ductile and the surface holds lubricant well for severe drawing operations.

2B—Steel in the 2D condition which is subsequently rolled on a "skin pass" or temper mill. The surface acquires a bright finish from the polished rolls. This surface is somewhat more dense and hard than 2D and is a better starting surface for later finishing and buffing operations.

No. 3—This surface is made by grinding with a No. 100 abrasive. This surface is smooth but not as reflective as 2B.

No. 4—A finer finish than No. 3 made by grinding with a No. 150 abrasive. Like No. 3, this surface is easily blended with hand grinders after forming, drawing or welding.

No. 7—Good reflectivity and brilliance made by polishing with a No. 400 abrasive. This semi-mirror finish must be protected during fabrication by adhesive paper or strippable plastics lest the finish be marred beyond repair.

BRIGHT—A highly reflective surface made by cold reducing with highly polished, glass-hard rolls. This finish is only available in Type 430 stainless.

These are our standard surface finishes that are available in types 201, 202, 301, 302, 304 and 430 except Bright which is type 430 exclusively.

These finishes are regularly supplied in sheet and coil form in widths up to 48 inches.

Since Nos. 3, 4, 7 and 430 Bright are smooth reflective surfaces, they are not recommended for severe drawing without special precautions as the mill finish may be marred. Applications such as dairy machinery, kitchen and restaurant equipment and architectural decorative work require only local forming, so these highly polished surfaces are not greatly disturbed. All mill polished sheets are carefully packed to avoid handling imperfections. Protective adhesive paper can be specified by the buyer when needed.

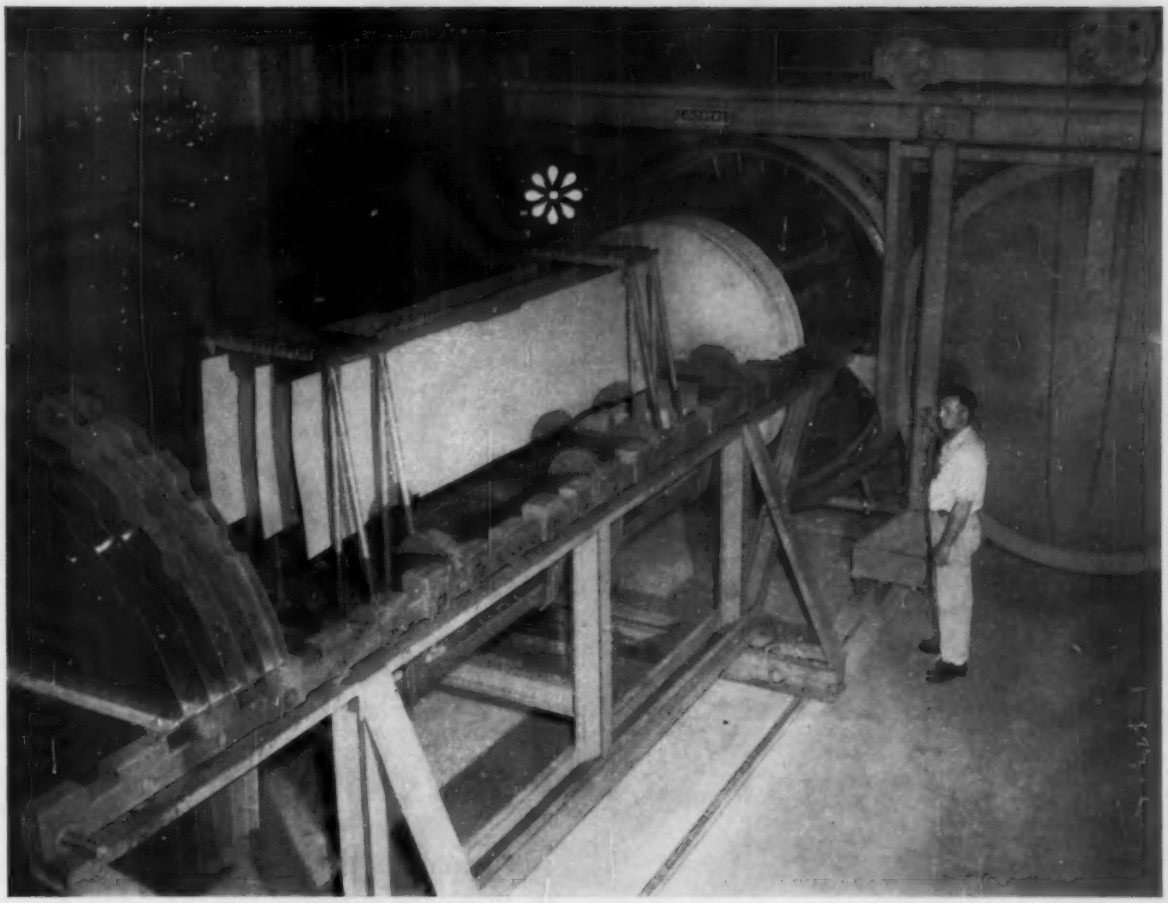
For specific information on recommended surface characteristics for a particular stainless steel sheet and strip application, address your request to our Product Development Dept.

WASHINGTON STEEL CORPORATION — MicroRold — STAINLESS — SHEET & STRIP

Washington Steel *Corporation*

Producers of Stainless Sheet and Strip Exclusively

10-T WOODLAND AVENUE, WASHINGTON, PA.



Giant retort runs at 2100°F and 0.3 microns vacuum...half-inch Inconel prevents collapse

There are many vacuum furnaces.

But, so far as we know, none so big (the work chamber is 14 feet long by 6 feet in diameter), runs so hot, at so high a vacuum.

As in other vacuum furnaces operated at high temperature, the retort in this one is Inconel* nickel-chromium alloy.

There are three good reasons for this. First, Inconel alloy is strong, highly resistant to oxidation. Half-inch plate is ample to prevent collapse. Second, Inconel alloy provides long-term insurance against damage caused by thermal shock. Third, no commercially available wrought alloy of comparable capabilities is easier to fabricate in large and heavy sections.

If you are designing equipment for high temperature service, take a tip from the men who are building the units that operate under extreme conditions. Consider Inconel alloy.

To make your planning easier, write for the Inco booklet, "Keeping Costs Down When Temperatures Go Up." You'll find it's packed with pictures and descriptions of successful equipment. *Registered trademark

The International Nickel Company, Inc.
67 Wall Street New York 5, N.Y.

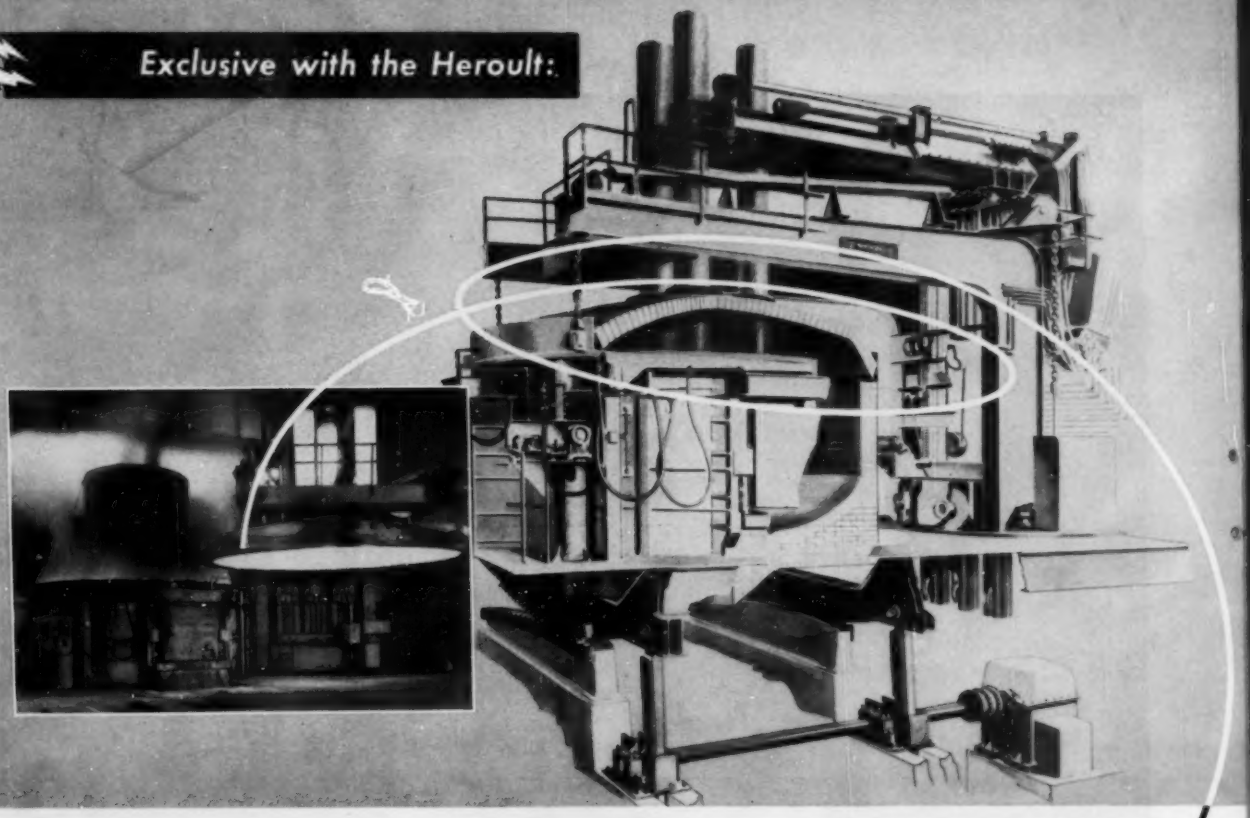
INCO

***Vacuum heat treats full-sized sheets**

This gigantic electrically operated vacuum furnace degasses and anneals large forgings, extrusions and full-sized titanium alloy sheets in the flat. A unique internal tube cooling system sets "honeycomb sandwich" brazed joints prior to transfer of the assemblies into the unit's cooling chamber. Overall, the unit exceeds 40 feet in length. The vacuum system (F. J. Stokes Company) evacuates its 1400 cu. feet to 0.3 microns in 23 minutes. The facility was built for North American Aviation's Missile Development Division by Lindberg Engineering Co., Chicago, Ill.

INCO NICKEL ALLOYS

Exclusive with the Heroult:



Water-cooled Skew Back Roof Ring

One of the features of the new Heroult is its low-cost maintenance. It is designed to make bricking easy and economical. Even the repair of the removable roof can be accomplished in much less time and with less labor and material cost. For the Heroult is the only electric furnace on the market with a water-cooled, skew-back type of roof ring. This patented design feature eliminates the need of special skew-shaped brick.

Embodying the latest in mechanical and electrical equipment, these widely used furnaces are noted for efficient performance and low operating and maintenance costs.

They are available in size of shell diameter ranging from 7'0" up to 24'6", and with rated charge capacity of from 8000 lbs. up to 400,000 lbs. They are equipped with removable roofs to permit top charging. Both gantry and swing-type roof-removing mechanisms are available. Door-charging furnaces and furnaces of special design, including units equipped with non-magnetic steel bottoms to permit induction stirring, can be supplied.

We welcome an opportunity to help you select and install the Heroult best suited to your needs.

The Heroult is the only 100% mechanically operated electric furnace

All of the movements of the Heroult are handled by motor-driven gear mechanism. This is a very important advantage, for it eliminates many maintenance difficulties. Your own maintenance man can easily keep this modern electric furnace performing efficiently with a minimum of service.

This and other Heroult exclusives, such as cage-type shell construction, independently supported operating mechanism, and water-cooled skew-back roof ring, make the Heroult the finest electric melting furnace on the market.

Ask for latest catalogue

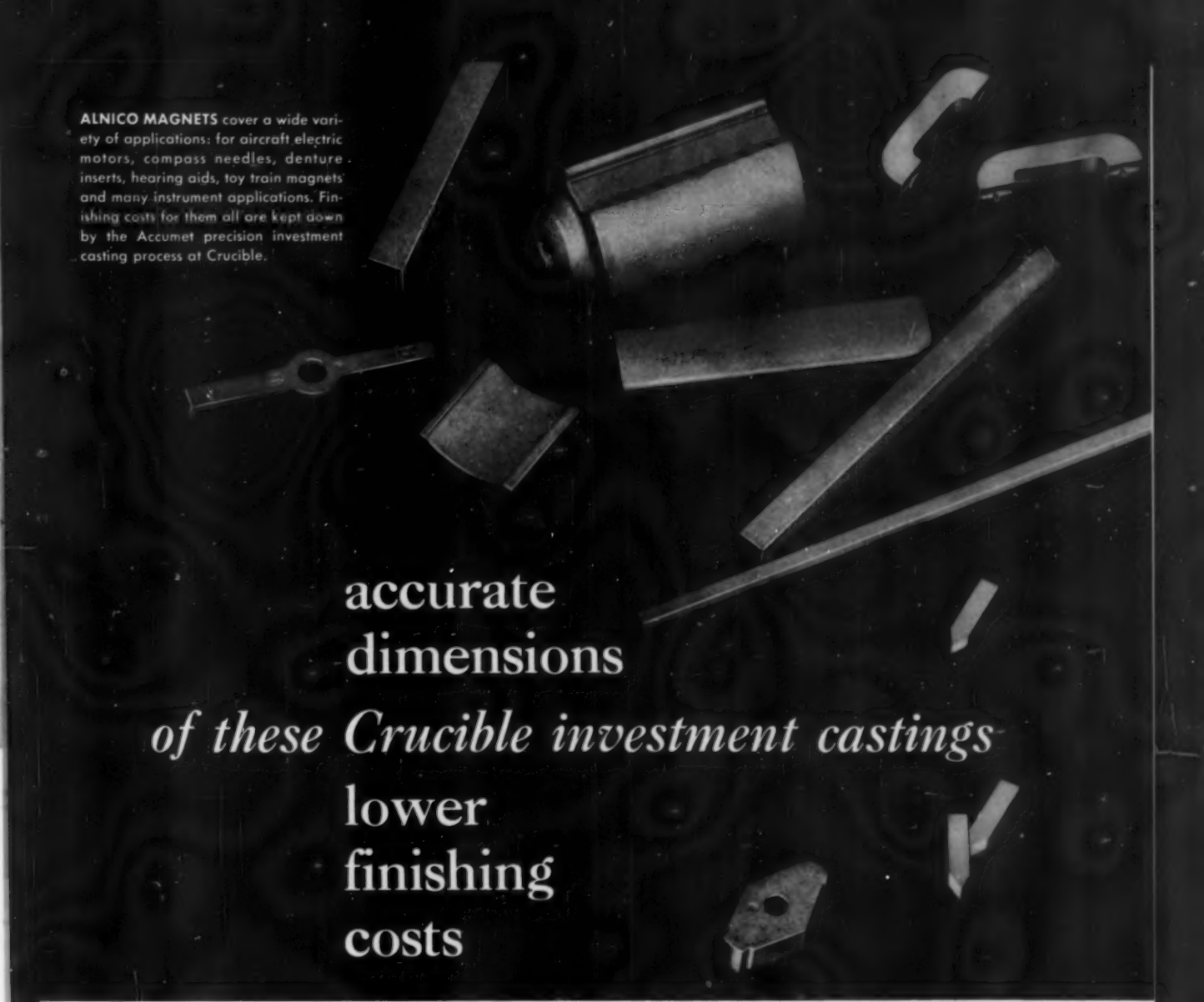
This free catalogue will help you determine how Heroult Electric Furnaces can improve your operation . . . and enable you to make better quality steels. Tells you where and when an electric furnace is desirable. Gives furnace types, sizes, capacities and ratings. For your free copy, just contact the office nearest you, or write direct to Pittsburgh.

Heroult
ELECTRIC
MELTING FURNACES

AMERICAN BRIDGE DIVISION
UNITED STATES STEEL CORPORATION, GENERAL OFFICES:
525 WILLIAM PENN PLACE, PITTSBURGH, PA.
Contracting Offices in New York, Philadelphia, Chicago, San Francisco and other principal cities.
United States Steel Export Company, New York

USS

UNITED STATES STEEL



ALNICO MAGNETS cover a wide variety of applications: for aircraft electric motors, compass needles, denture inserts, hearing aids, toy train magnets and many instrument applications. Finishing costs for them all are kept down by the Accumet precision investment casting process at Crucible.

accurate dimensions *of these Crucible investment castings* lower finishing costs

Because the castings in the picture are Alnico magnets, their finishing usually calls for costly grinding operations. That's because Alnico materials are hard and brittle. These castings, however, need virtually no finishing at all. The reason is to be found in the type of casting: Crucible Accumet® precision investment casting.

Crucible uses hot molds with special inner linings for producing Accumet precision investment castings which give two advantages: (1) they turn out castings to close tolerances, and (2) they produce surfaces that are exceptionally fine. These two advantages virtually eliminate all finishing operations. Crucible precision investment castings are available in a complete range of stainless, tool, and alloy steels, as well as Alnico permanent magnets.

For detailed information, write for booklet on "Crucible Accumet Investment Castings". Or you can find out exactly what type of castings you need by calling your Crucible representative.

Crucible Steel Company of America, The Oliver Building, Mellon Square, Pittsburgh 22, Pa.

CRUCIBLE first name in special purpose steels

Crucible Steel Company of America

Canadian Distributor — Railway & Power Engineering Corp., Ltd.

VISIT

BOOTH 1735

National Metal Exposition & Congress
International Amphitheatre
Chicago—November 4-8

NATIONAL Malleable Iron

HTM Pearlitic Malleable Iron

NACO Carbon Steel

NACO Alloy Steel

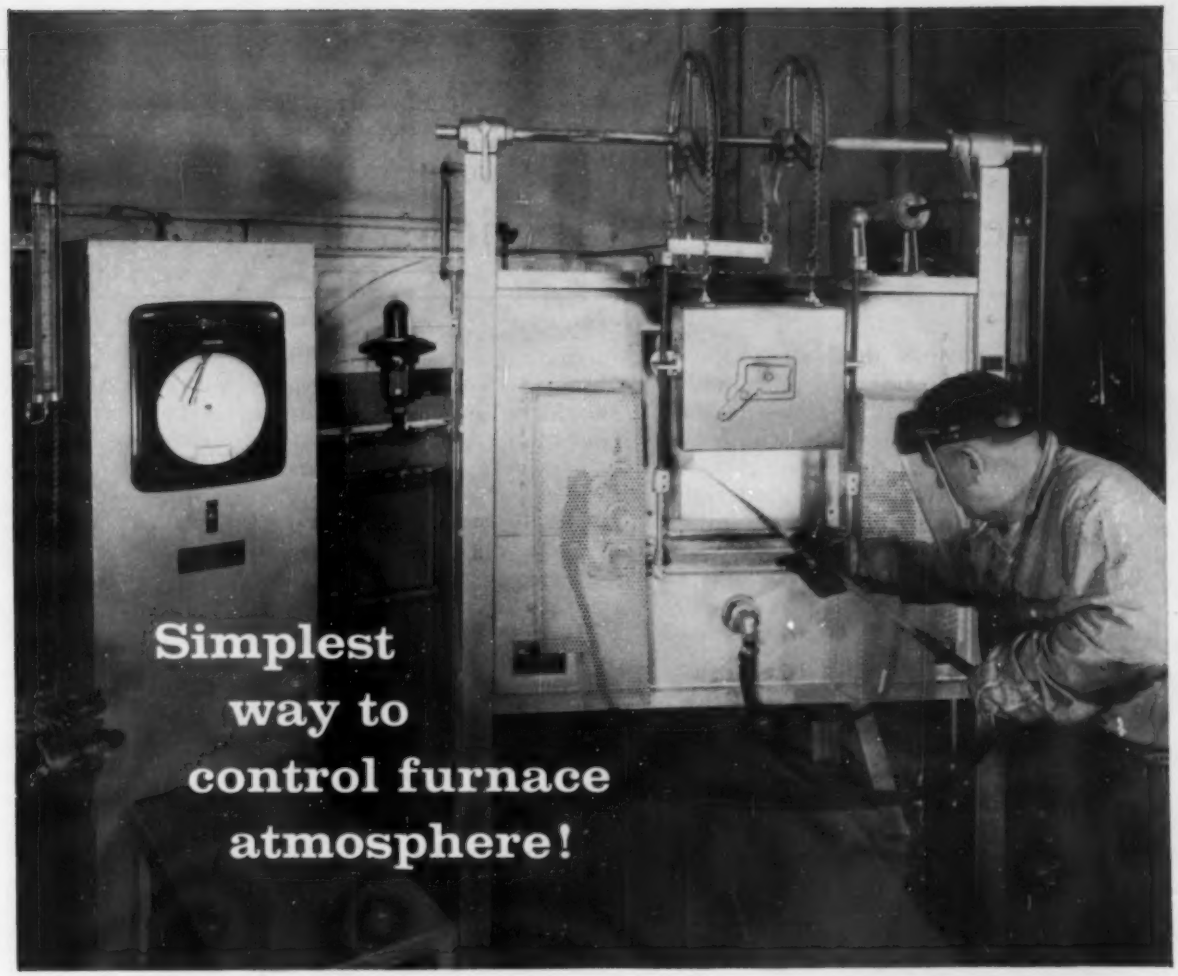
NACO Manganese Steel

NATCO Gray Iron

NATIONAL Malleable and Steel **CASTINGS COMPANY**

Established 1868 *Cleveland 6, Ohio*

AA-6400



Foxboro Dew Point Control on C. I. Hayes Hardening Furnace at W. H. Nichols Company, Waltham, Mass. Gears and other parts used in the production of Nichols' rayon and nylon pumps are treated in this furnace at temperatures of approximately 2250°F. Foxboro Control Valve at right of controller precisely regulates flow of propane gas to furnace . . . holds furnace moisture at pre-set value.

. . . FOXBORO Dew Point Control

It's a cinch to maintain proper moisture conditions in *any* atmosphere furnace equipped with Foxboro Dew Point Control. This advanced control system is the easiest to operate — easiest to maintain. Here's how it works . . .

The unique Foxboro Dewcel* element continuously "senses" the dew point of a running sample of the furnace gas. The Foxboro Controller continuously records this value and automatically regulates the generator or corrective device for optimum moisture content at all times. The only maintenance this system requires is occasional rinsing and "re-wetting" of the Dewcel element!

Foxboro Dew Point Control is available for measurement and control of dew point as low as −30°F dew point, and up to +142°F dew point. It provides positive protection against decarb, etching, scaling, and carbon deposit caused by incorrect atmosphere. For better production of a better product in *your* heat treat, get full details on Foxboro Dew Point Control. Write **The Foxboro Company 5210 Neponset Ave., Foxboro, Mass., U. S. A.**

*Reg. U. S. Pat. Off.

FOXBORO
REG. U.S. PAT OFF.

CONTROLS for the METALS INDUSTRIES

XXIV

This is the twenty-fourth of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

Quenching and Tempering Alloy Steels

Of the various methods of heat-treating alloy steels, the most important is that involving quench and temper. This method, which enhances the mechanical properties of the end product, differs materially from normalizing and annealing (previously discussed in this series).

The purpose of quenching is to effect a cooling rate sufficient to develop the desired hardness and structure.

Before quenching takes place, steel is heated to a point above the transformation range. Quenching is the subsequent immersion of this heated steel in a circulated or agitated bath of oil, water, brine, or caustic; or, in the case of austempering or martempering, generally in agitated molten salt baths. Austempering and martempering are preferable where a minimum of distortion is desired.

Quenching *increases* the tensile strength, yield point, and hardness of alloy steels. It *decreases* ductility —that is, elongation and reduction of area. It also decreases resistance to impact. However, by means of tempering, it is possible to restore some of the ductility and impact-resistance—but only at a sacrifice of tensile strength, yield point, and hardness.

The results of mild oil- or water-quenching as related to mass effect can be found in the end-quench hardenability test. Voluminous data concerning this test are issued by AISI and SAE in the form of hardenability bands for the various grades of alloy steels.

If thermal cracking is to be avoided, cooling by liquid quenching should not be carried to a point below 150 deg F. When a temperature of 150 deg F is approached, immediate tempering should follow. Because of residual stresses, no steel should be used in the as-quenched condition.

Tempering can be defined as reheating to a specified temperature below the lower critical range, followed by air cooling. It can be done in furnaces, oil, or salt baths, the temperatures varying from 300 to 1200 deg F. With most grades of alloy steel, it is best to avoid temperatures between 500 and 700 deg because of the "blue brittleness" that occurs in this range. Maximum hardness and wear-resistance result from tempering at low temperatures; maximum toughness is achieved by tempering at the higher levels. Of course, one of the essential reasons for tempering is to relieve the residual stresses set up in quenching.

Bethlehem metallurgists have devoted years of study to quenching, tempering, and other phases of heat-treating. By all means call them if they can be of service to you. And please remember, when you are next in the market for alloy steels, that Bethlehem makes all AISI standard grades, as well as special-analysis steels and the full range of carbon grades.

If you would like reprints of this series of advertisements from No. I through No. XX, please write to us, addressing your request to Publications Department, Bethlehem Steel Company, Bethlehem, Pa. The first 20 subjects in the series are now available in a handy 36-page booklet, and we shall be glad to send you a free copy.

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. *Export Distributor:* Bethlehem Steel Export Corporation

BETHLEHEM STEEL

No. 1950

ULTRASONIC CLEANER FOR METALLOGRAPHY

No. 1952 Positioning Clamp and Automet Holder

This new scientific development is ideal for cleaning metallographic specimens. It removes the hazard of carrying abrasive particles from a coarse grinding stage on to a finer grinding stage. The cleaning is accomplished quickly, thoroughly and at low operating cost. No skill is required. Additional speed and convenience is achieved by using an additional Transducer Beaker. The positioning clamp is required to accommodate the specimen holder from the Buehler Automet automatic polishing attachment.

A New Electro Polisher and Power Operated Press with other Buehler products will be exhibited at the

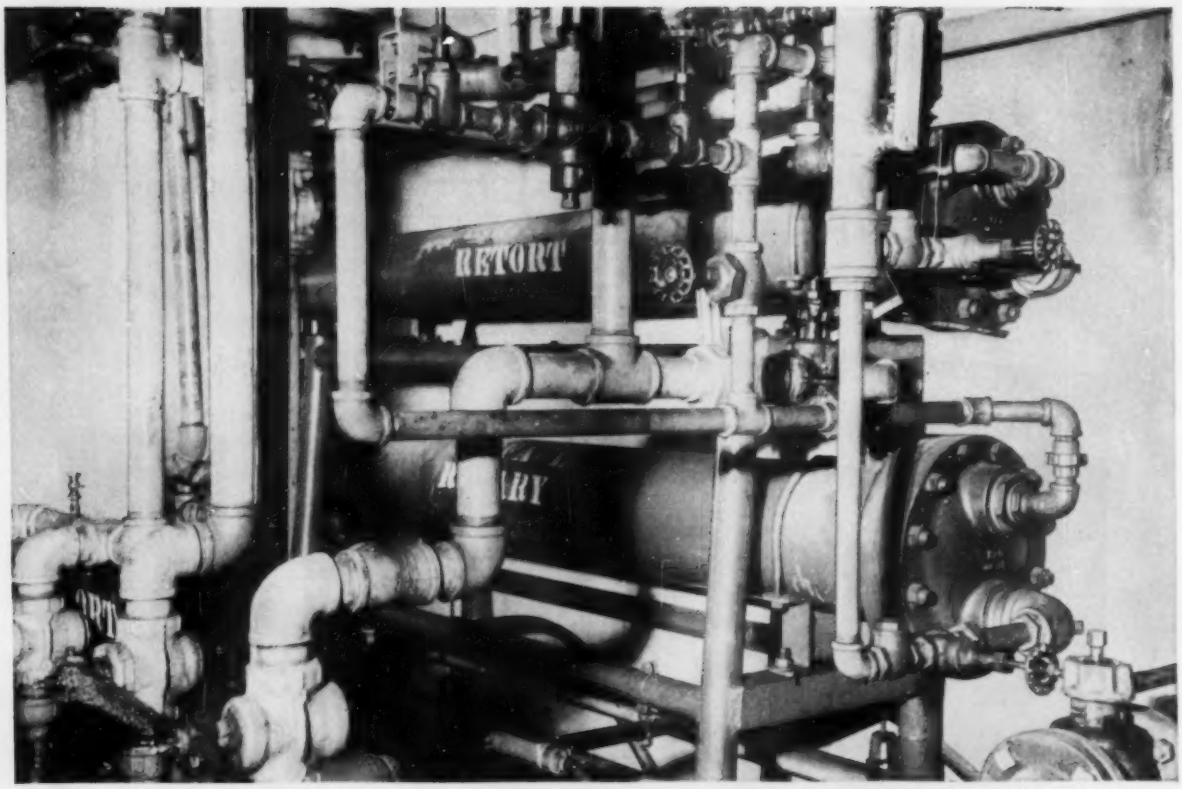
NATIONAL METAL EXPOSITION

BOOTH 1235 CHICAGO, Nov. 4-8

Buehler Ltd.

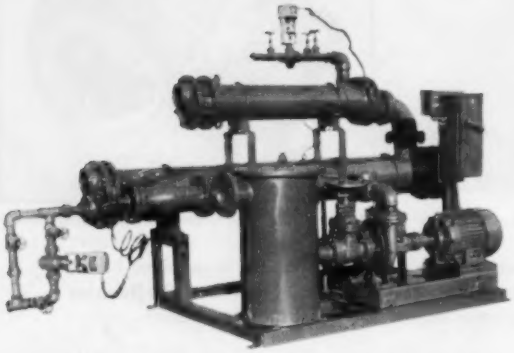
METALLURGICAL APPARATUS

2120 GREENWOOD ST., EVANSTON, ILLINOIS, U.S.A.



B&G *Controlled* QUENCH OIL COOLING

helps CHRYSLER maintain uniform quality of heat treated parts



COMPLETELY SELF-CONTAINED UNITS

B&G *Hydro-Flo* Self-Contained Oil Coolers combine Coolers, Motors, Strainers and all controls into single, integrated units. Fully automatic, they keep oil temperature at the desired degree through all stages of the quench. Your only responsibility is to connect to the quench tank and water lines. Units can be easily moved if ever necessary.

This combined Catalog and Selection Manual gives full information on B&G Self-Contained Oil Coolers. Send for your copy.

In the Chrysler Automatic Transmission Plant at Indianapolis, Indiana, holding uniform quality of heat-treated parts is aided by *controlled* quenching with B&G oil cooling equipment.

A B&G *Hydro-Flo* Oil Cooling System eliminates the warping and quality variations caused by uncontrolled quenching. The oil in the quench tank is kept constantly at whatever temperature is desired and at maximum turbulence. Each group of parts passing through the operation is processed under identical conditions, thus insuring consistent quality.

B&G Oil Cooling Systems may be purchased as complete "packages" or as component parts for assembly on the job. B&G Quench Tanks are also available—either in standard designs or built to your specifications.

The B&G engineering department is always at your service.

B&G

Hydro-Flo* **OIL QUENCHING SYSTEMS**

BELL & GOSSETT COMPANY

Dept. EZ-16, Morton Grove, Illinois

Canadian Licensee: S. A. Armstrong Ltd., 1400 O'Connor Drive, Toronto 16

*Reg. U.S. Pat. Off.

YOLOY "E" IS ON THE JOB

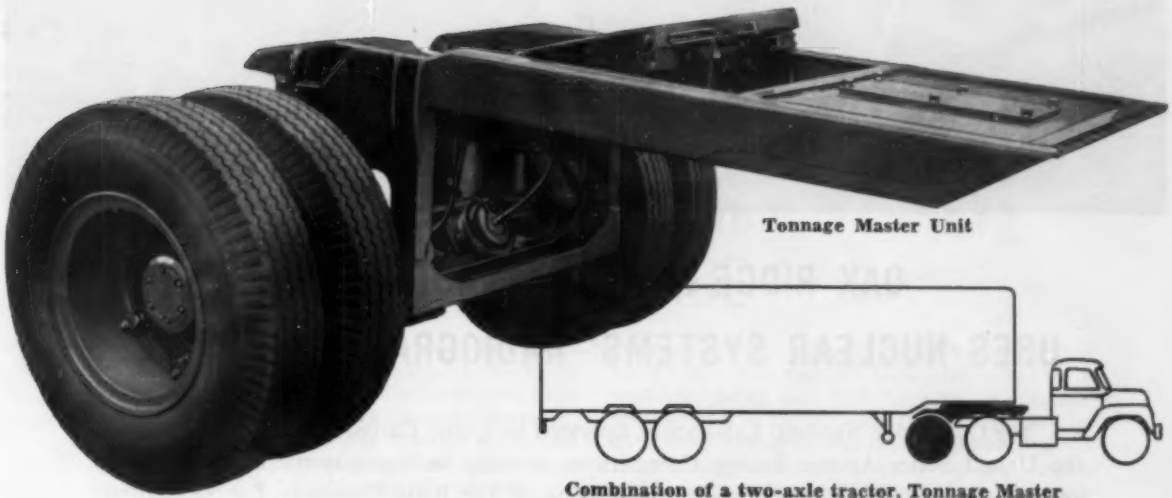
. . . providing increased strength, corrosion and impact resistance for Fruehauf's new "Tonnage Master"

This "extra axle" conversion assembly, built exclusively by Calumet Tonnage Master Fabricators, Inc., for the Fruehauf Trailer Company, enables truck operators to get maximum performance from their existing equipment.

Riding behind a two-axle tractor, a Tonnage Master provides increased load carrying capacity, reduction in tractor wheelbase, improved traction on curves, increased tire life as well as easier riding through utilization of more springs.

All components—except springs and axles—are fabricated from Youngstown's Yoloy "E" high strength-low alloy steel. This versatile steel was wisely specified to provide the units with longer life, increased resistance to shock, vibration and corrosion, as well as lighter—yet stronger—construction.

Youngstown's complete family of Yoloy steels is available in Sheets, Plates, Bars, Shapes, Cold Drawn Bars and Tubular Products. Complete informative Data Sheets on each Yoloy steel will be promptly sent upon request.



Tonnage Master Unit

Combination of a two-axle tractor, Tonnage Master and a dual-axle trailer provides five axles for carrying top loads at greater safety.

Write for these free pamphlets in The Yoloy Family series:	
YOLOY "E"	High Strength Low Alloy Steel—standard applications
YOLOY	High Strength Low Alloy Steel—special applications
YOLOY "S"	Higher Strength Steel for increased service life
YOLOY "C"	Corrosion Resistant Grade for deep forming
YOLOY PIPE	Continuous Weld for corrosion resistant applications

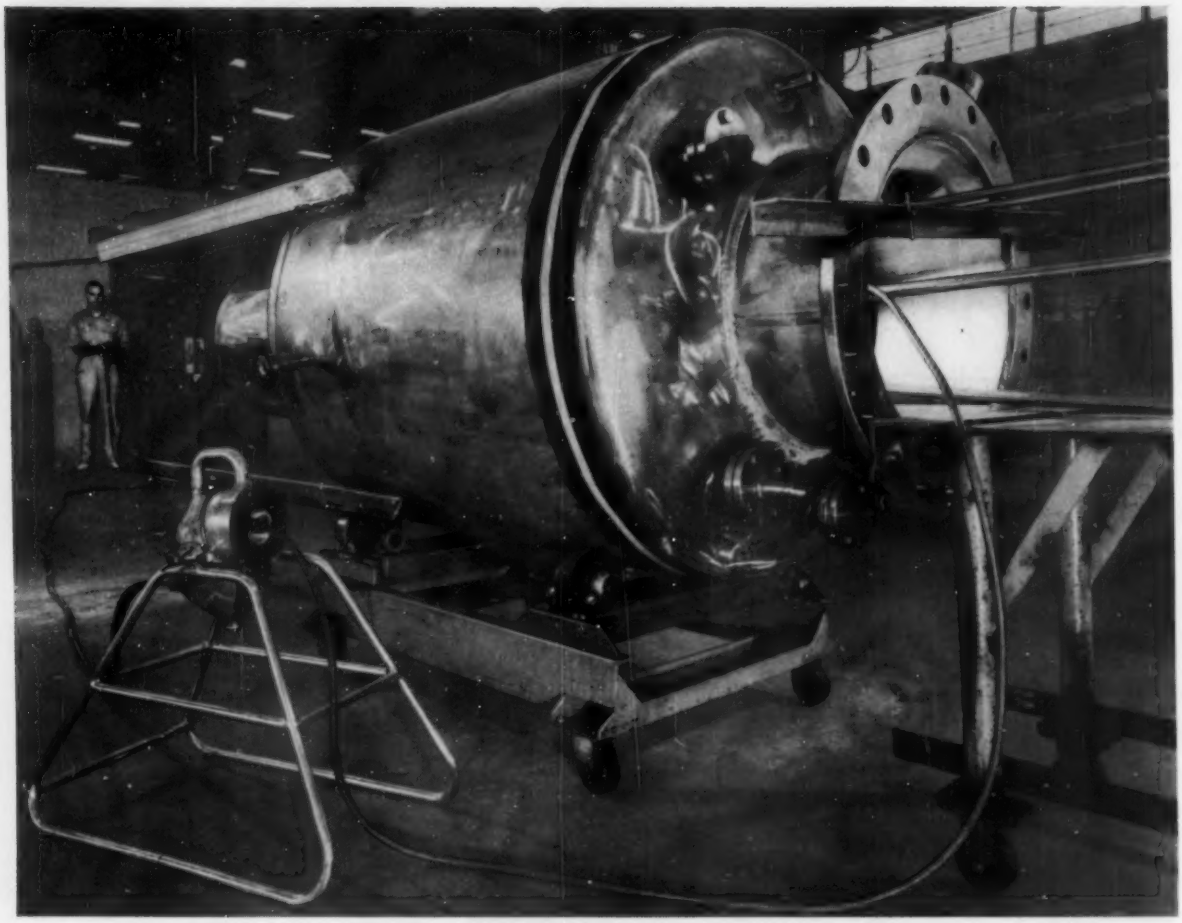
QUALITY YOUNGSTOWN SERVICE

THE YOUNGSTOWN SHEET AND TUBE COMPANY

Manufacturers of Carbon, Alloy and Yoloy Steel

General Offices - Youngstown 1, Ohio

District Sales Offices in Principal Cities



OAK RIDGE NATIONAL LABORATORY USES NUCLEAR SYSTEMS' RADIOGRAPHY MACHINES

The Oak Ridge National Laboratory, operated by Union Carbide Nuclear Company for the United States Atomic Energy Commission, is using radiography machines developed and manufactured by Nuclear Systems, a division of The Budd Company, for their atomic research activities.

Shown above is an operator using Nuclear Systems' Model 30, checking a circumferential weld on a fabricated stainless steel pressure vessel, an evaporator used for waste disposal processing of radioactive materials.

Within 10 minutes the operator can make an *internal* exposure of a complete circumferential weld, using iridium 192.

Weighing only 55 pounds, the Nuclear Systems' radiography machine Model 30 is ideally designed for portability and in-shop exposures.

NUCLEAR SYSTEMS
A DIVISION OF THE BUDD COMPANY, Philadelphia 32
Budd

Tough and Rough!

Bulk Airco tungsten carbide bonded to a pellet mill roller by shielded arc welding form a tough, abrasive surface.

3 TIMES LONGER LIFE FOR PELLET MILL ROLLERS *with* AIRCO TUNGSTEN CARBIDE

The preparation of animal feed is extremely severe on pellet mill rollers which are subject to the highly abrasive chemical additives used in the mixture. Ordinary hardfacing materials failed to extend the service life of these rollers sufficiently to satisfy the Sprout-Waldron Company, Pennsylvania manufacturer of equipment used in the cattle and feed industry.

An Airco Technical Sales representative tackled the problem. After extensive experiments, tungsten carbide was welded to the rollers, using Air Reduction's inert gas–shielded arc process–Heliwelding. The rollers were then put into service at one of Sprout-Waldron's customer plants.

The operation was a complete success. The rollers protected by Airco tungsten carbide lasted 2 to 3½ times longer than regularly hard-faced rollers. In a production set-up using bulk Airco tungsten carbide, Sprout-Waldron has also reduced welding time by 25%. And further savings are realized because the tungsten carbide forms a hard, abrasive surface which eliminates the need for grinding welds smooth and cutting slots in the face of rollers.

Next to diamonds, tungsten carbide is the hardest commercial material known. If you have any problem concerning abrasion, call on our Technical Sales Service Dept. Let us show you how tungsten carbide–in bulk or electrode (Tungtube) form can provide resistance to abrasion in many applications.

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Products of the divisions of Air Reduction Company, Incorporated, include: **AIRCO** — industrial gases, welding and cutting equipment, and acetylenic chemicals • **PURECO** — carbon dioxide — gaseous, liquid, solid ("DRY-ICE") • **OHIO** — medical gases and hospital equipment • **NATIONAL CARBIDE** — pipeline acetylene and calcium carbide • **COLTON** — polyvinyl acetate, alcohols, and other synthetic resins.

WELDCO is available in Stainless Steel, Monel, Inconel, Nickel, Cupro-Nickel, and Hastelloy, in tube and pipe sizes from 3" to 30", Schedules 5, 10 and 40.

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Photo Courtesy of Newport News Shipbuilding and Dry Dock Co.

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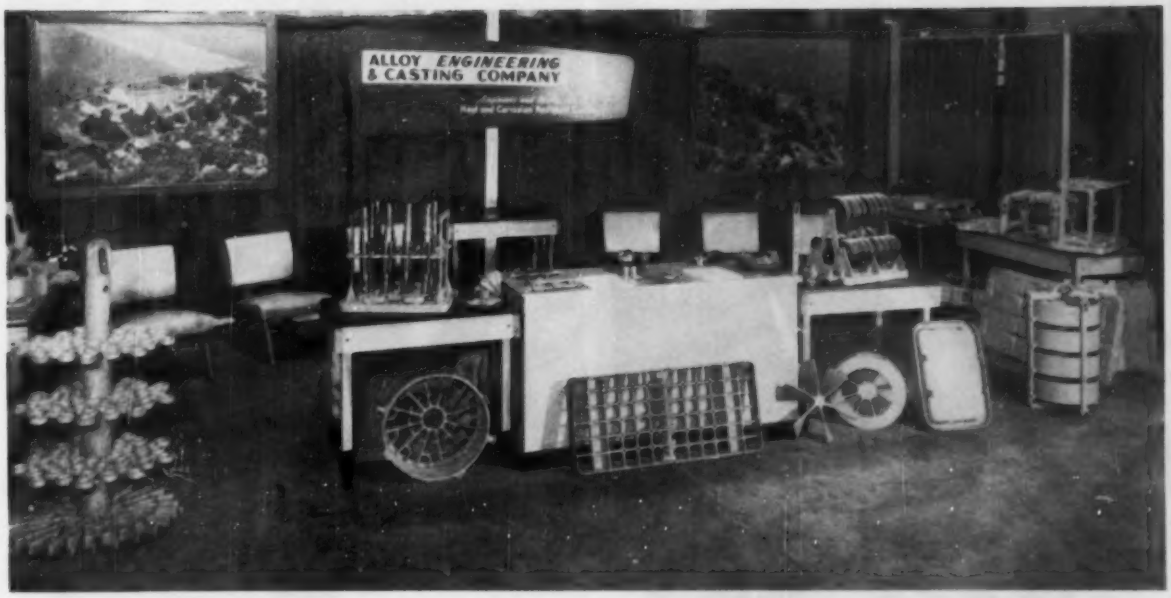

VISIT YOUR ACCOLOY ENGINEER IN BOOTH 442

We will be on hand again to welcome you to our exhibit at the National Metal Show in Chicago, Nov. 4-8. Stop and see for yourself the sensational records that are being made by companies using ACCOLOY Heat and Corrosion Resistant castings. Get the facts on the successfully operated heat treat departments that are showing a profit by following the advice of Accoloy Engineers, who study each individual project and follow through to insure a design that will give maximum service life far beyond the initial alloy cost. Get proof positive why ACCOLOY castings are still being "preferred by industry."

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This unretouched photograph shows deterioration of 25-12 alloy radiant tube after 10 months service.

This unretouched photograph shows radiant tube of 22H still in serviceable condition after 78 months service in the hot zone where temperatures averaged 1850°F.

22H establishes new service record!

Has provided five times longer service life for radiant tubes in annealing furnace... and still going strong

Faced with mounting production losses and increasing tube replacement costs, a manufacturer of continuous weld carbon pipe began to experiment with the new high temperature alloy 22H for the "W" type radiant tubes in his annealing furnaces.

After seven years of in-use testing in all heat zones of the furnaces, this user found that the service life of radiant tubes made of 22H was increased far beyond the performance range of radiant tubes made of 25-12 type alloy.

After a total of 78 months service in temperatures ranging from 1700 to 1925°F., the 22H tubes were found to be in good condition and still continue in service. A 25-12 tube installed in the same position failed after 10 months service.

Since its introduction eight years ago, 22H has proven itself in many applications where severe operating conditions and elevated temperature ranges are the rule.

A National Alloy engineer will be glad to show you further proof of performance, and to discuss the use of 22H in your operation.

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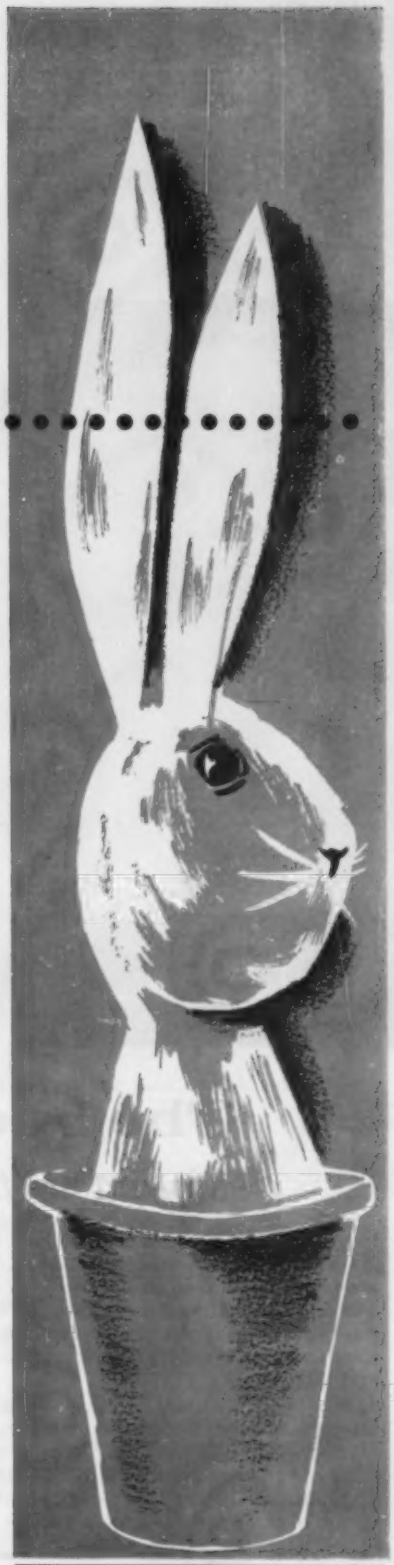

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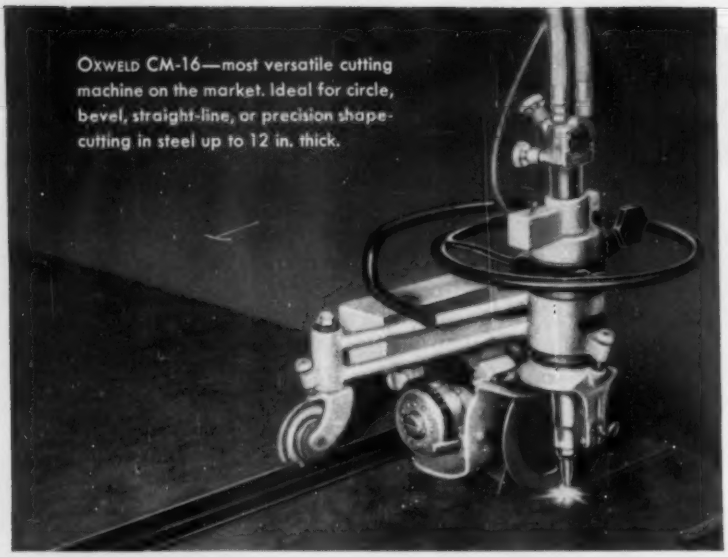

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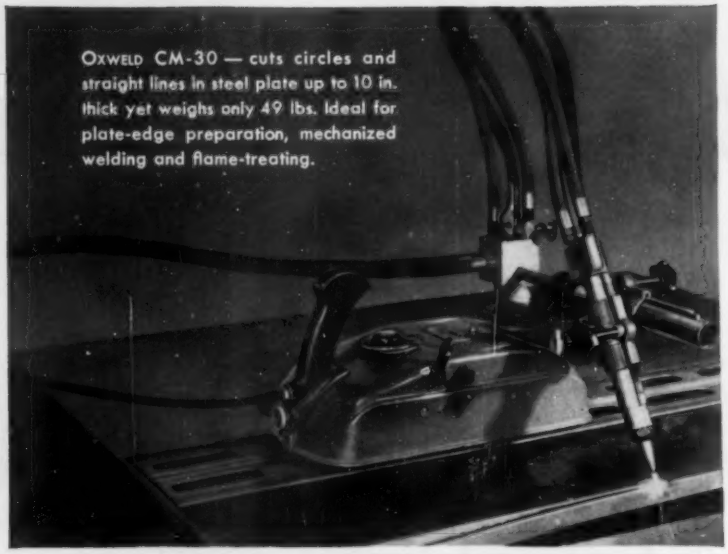
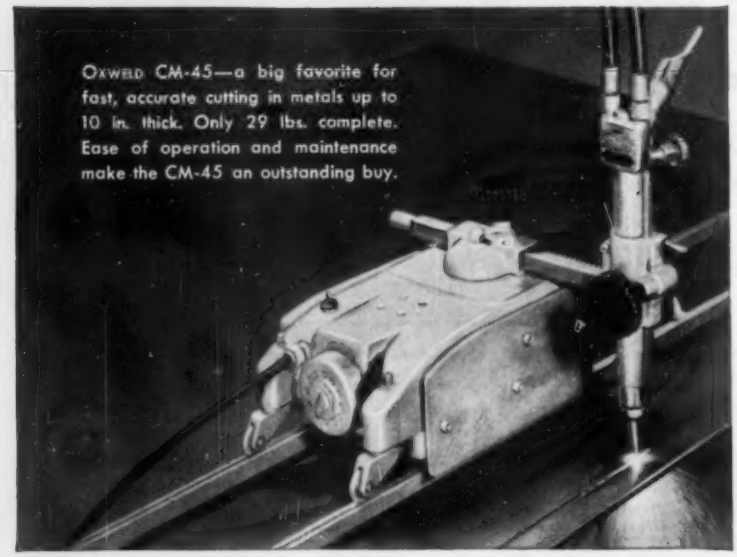


OXWELD CM-30 — cuts circles and straight lines in steel plate up to 10 in. thick yet weighs only 49 lbs. Ideal for plate-edge preparation, mechanized welding and flame-treating.



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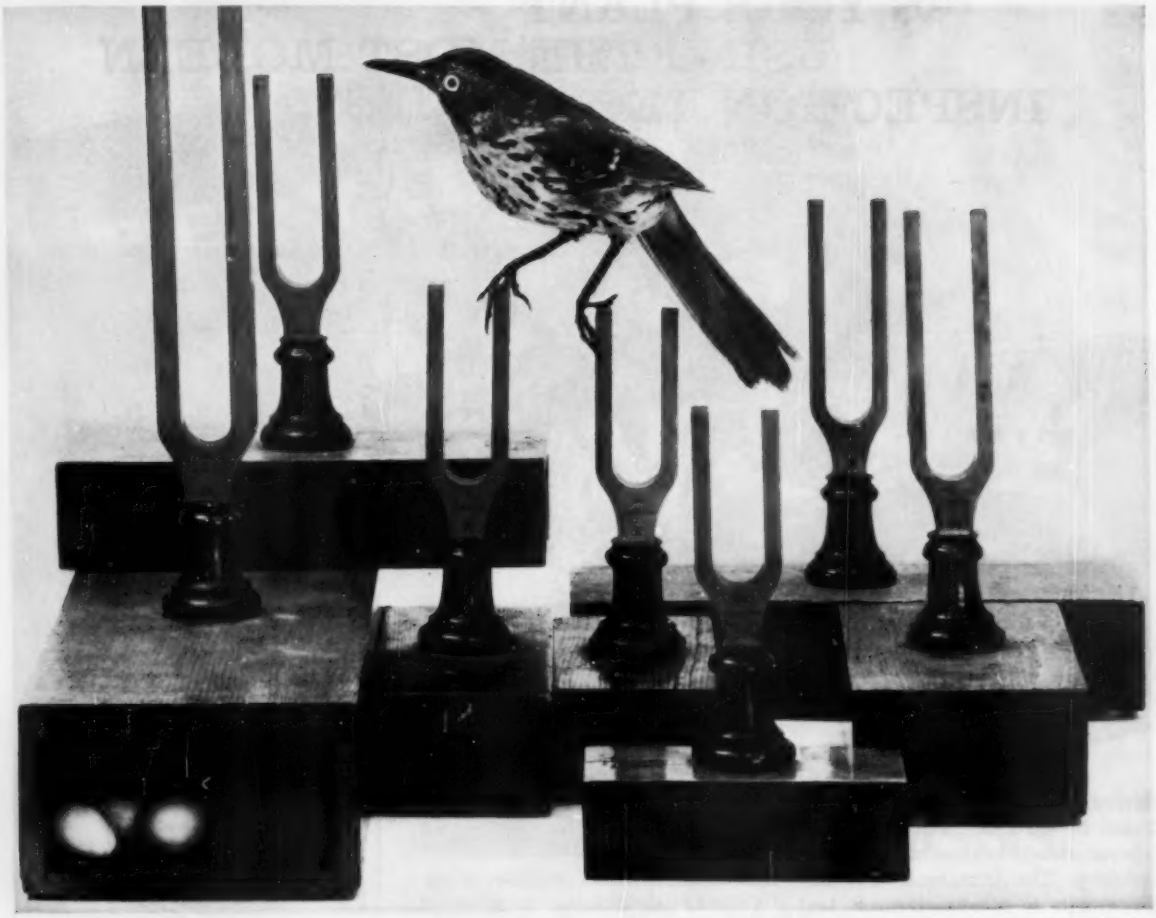

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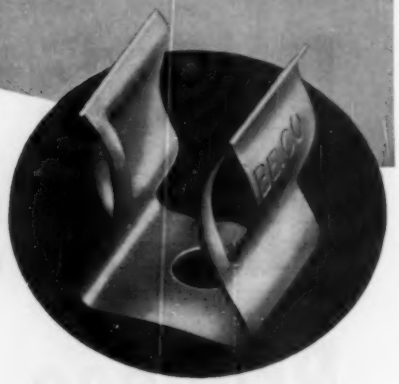

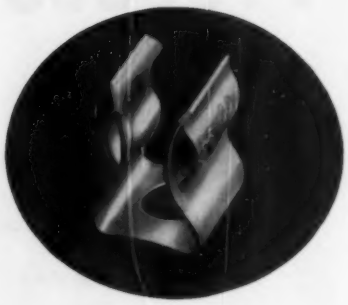

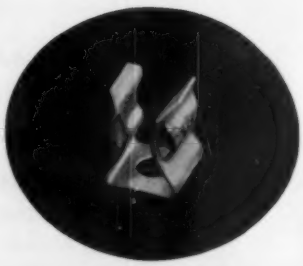

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In comparison, the alloy provides lower contact resistance and much higher conductivity than other possible clip materials, such as phosphor bronze.

Beryllium copper fuse clips greatly reduce contact point heating. They will not buckle or anneal at high temperatures. Clips of this alloy are immune to mechanical fatigue from rough and severe usage arising from the continuous insertion and extraction of fuses in the fuse clip.

THE BERYLLIUM CORPORATION
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TECHNICAL BULLETIN NO. 38

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PHYSICAL PROPERTIES OF "BERYLCO" 165 STRIP	
Specific Gravity	8.26
Density, lb. per cu in	0.298
Melting range, °F	1600-1800
Thermal expansion coefficient, per °C, 20° to 200°	0.0000170
Thermal expansion coefficient, per °F, 68° to 392°	0.0000094
Thermal conductivity, btu/sq ft/in/hr/°F at 68°F	750-900*
cal/sq cm/cm/sec/°C at 20°C	0.26-0.31*
Electrical conductivity, IACS % at 20°C	22-30*
Electrical resistivity, microhm cm at 20°C	7.8-5.7*

*Heat treated

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The American Society for Metals is known so favorably and so well by outstanding metals authorities that they have contributed their busy time, their valuable efforts and their expert abilities to the preparation of up-to-the-minute home study courses.

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Three years of intensive planning have gone into this new and modern approach to home study and in-plant training courses. As a student, you receive the beautiful 3-ring binder pictured above, stamped in attractive red, gold and black with the insignia of the Metals Engineering Institute.

You receive fifteen lessons in each course, lessons that thoroughly cover the study subject in up-to-the-minute detail. Each lesson is distinctively printed and clearly illustrated. When you have completed the course, these 15 lessons and the comments of your instructor will provide a permanent loose-leaf reference.

Another valuable study tool and reference feature of each course is the ASM Metals Handbook, supplied free as a regular part of your course. Upon enrollment, you will receive (1) the ASM Metals Handbook; (2) the attractive MEI Binder; (3) the first two study course lessons, and instructions for study. Then in your own spare time you complete your first lesson, return your quiz questions to the instructor assigned to you at MEI Headquarters. Then you can begin Lesson No. 2. Meanwhile, your MEI instructor goes over your answers to the Lesson No. 1, carefully grades and makes suggestions for you. These suggestions and comments are then returned to you, along with the Lesson No. 3. And so on. You always have a lesson in your hands. You have one going to M.E.I. and M.E.I. has one coming to you. This rotation is maintained to conveniently fit in with your own plans, your own available time.

ELEMENTS OF METALLURGY

Many outstanding authorities have contributed to this popular course edited by Ralph E. Edelman, Chief, Reactive Metals Section, Pitman-Dunn Laboratories, Frankford Arsenal, Philadelphia.

This is a practical course that deals with the behavior of metals in refining, heat treating, fabrication, electroplating and numerous other metalworking operations. It is a course that introduces the student who may have little prior knowledge of chemistry or physics to a down-to-earth study of metallurgy.

Paul R. Brucker, Metallurgist, Crucible Steel Co. of America, Midland, Pa., joins Mr. Edelman in preparation of the first five lessons of "Elements of Metallurgy". *Lesson No. 1* lays the groundwork for an understanding of metallurgy in an examination of the structure of metals, the behavior of atoms and molecules. Following this study of the chemical nature of metals, *Lesson No. 2* concentrates on the physical side and the problems of measurement, expansion, mass and energy, heat transfer and the like.

The chemical changes, or reactions, that take place between elements, between compounds, or between elements and compounds are discussed in *Lesson No. 3*, with *Lesson No. 4* reviewing what happens in any given instance with specific elements in chemical reactions and with the effects of heat and temperature. *Lesson No. 5* points out that the chemical reactions that involve oxides are the foundation for the chemistry of refractories, smelting and combustion, and these are discussed.

Smelting and refractories and metal refining are subjects of *Lessons 6 and 7*, and are prepared by Edward D. Hinkel, Jr., Metallurgist, Carpenter Steel Co., Reading, Pa., with Mr. Edelman. Various smelting processes are described and necessary equipment is illustrated with cut-away charts and pictures. Refining processes that are required to produce a finished alloy from the metal produced by the smelting operations are then presented.

In *Lesson No. 8*, William McNeill, Electrochemist at Frankford Arsenal joins Mr. Edelman in a thorough discussion of electrolytic metallurgical processes, while in *Lesson No. 9*, Harry W. Antes, Metallurgist at Frankford cooperates with Mr. Edelman in an examination of what takes place when refined metals that are poured into ingot molds change from liquid to solid. In *Lesson No. 10*, Leonard Rubin, Research Assistant at Massachusetts Institute of Technology, writes with Mr. Edelman a more detailed discussion of metals structures in this solid state.

Five additional lessons cover heat treatment, precipitation hardening, diffusion and surface treatments, methods of forms and mechanical testing to provide an authoritative study, a practical presentation of a vital area in the metal industry. Mr. Edelman is well qualified to edit this fine course with his experience as Senior Metallurgist, Wright Aeronautical Corporation . . . Staff Metallurgist at Los Alamos Scientific Laboratories . . . Instructor, Metallurgy Extension, Pennsylvania State University . . . prior to his present position with Frankford Arsenal.

HEAT TREATMENT OF STEEL

One of the basic requirements in the processing of steels is their correct and efficient heat treatment. This outstanding, up-to-the-minute steel treating course fills the bill exactly with 15 authoritative lessons prepared by George F. Melloy, Research Engineer, Bethlehem Steel Co., Bethlehem, Pennsylvania.

Scores of pictures, charts and tabular matter are presented by Mr. Melloy in this practical coverage of all important aspects of the Heat Treatment of Steel. You will find this an interesting, helpful study, and a handy, day-by-day reference in the future.

Steel is a versatile material, Mr. Melloy points out in *Lesson No. 1*. He discusses what steel is, what properties make it useful and important, how these properties are measured and evaluated. He covers elasticity, plasticity, tensil testing and other important aspects. *Lesson No. 2* discusses the structure and mechanical properties . . . constitution of steel . . . effect of alloying elements and of heat treatment on mechanical properties.

Lesson No. 3 discusses relationship between structure of steel and its mechanical properties and the two basic methods of controlling structure and hence mechanical properties. *Lesson No. 4* describes annealing of steel—process of heating and cooling to reduce hardness . . . discusses procedures of altering and controlling structure of steel.

Hardening of steel is the subject of *Lesson No. 5*, and Mr. Melloy points out that only in modern times have these principles been understood. Maximum benefits from hardening were not realized until fairly recently. He shows how you can take full advantage of steel with proper hardening processes. *Lesson No. 6* continues a discussion of hardness and the factors involved . . . tests . . . and application of hardenability data.

Factors affecting hardness and hardenability are presented in *Lesson No. 7*, and include effects of carbon . . . alloying . . . quenching and miscellaneous factors. *Lesson No. 8* brings you up-to-date on tempering . . . its three stages . . . effect of temperature and time, of chemical composition and structure . . . of cooling practices.

Surface hardening of steel is discussed in *Lesson No. 9* and includes flame, induction and liquid salt hardening. Heat treatment of cast iron and cast steel described in *Lesson No. 10*, with *Lesson No. 11* discussing protection during heat treatment against decarburization and scaling. Heat treating furnaces, fuels and temperature control are reviewed in *Lesson No. 12*.

Lesson No. 13 outlines the failures and defects to look out for in heat treatment, and *Lesson No. 14* describes grain size—its control and effect. Final *Lesson No. 15* deals with the important area of tools steels—water hardening, shock resisting, nondeforming, hot work and high speed steels.

Mr. Melloy's work on this outstanding course is backed by long years of experience at Bethlehem Steel Company. He is a graduate of Lehigh University with a degree in Metallurgical Engineering, has been an instructor at the Bethlehem Center of the Mineral Industries Extension Services, Pennsylvania State University.

THESE COURSES

". . . Makes my work more interesting . . ." says Student

Glen C. Boyce, Chemist and Foreman of the Iowa Malleable Iron Co., Fairfield, Iowa, selected "Elements of Metallurgy" as his M.E.I. study. He writes "I am enjoying this course very much. The fact that the study material parallels my work makes both my work and studies a *great deal more interesting.*"

Executives, engineers, supervisors and production men are taking this in-plant training course on the "Elements of Metallurgy" at Cleveland Pneumatic Tool Co., Cleveland. Dr. Anton deSales Brasunas, Director of Metals Engineering Institute is teaching this class of 22 students. Training Directors and employers have shown great interest in these metals training courses for management, engineering, production and sales executives.

HIGH TEMPERATURE METALS

One of the most timely home study courses available anywhere . . . this course on High Temperature Metals by Dr. C. L. Clark, Metallurgical Engineer, Timken Roller Bearing Co., Canton, Ohio, authoritatively covers a broad, vitally essential area.

Fifteen lessons are packed with updated information, filled with 287 helpful illustrations. Keyed to references in the ASM Metals Handbook (a part of the study course), Dr. Clark provides a step-by-step climb to expert knowledge.

Jet engines, modern automobiles . . . the electricity you use . . . the high quality gasoline . . . all these are made possible by high temperature metals, and the surface of tomorrow's use is yet to be scratched. Here is a field where the *expert you can become* knows no limits.

Lesson No. 1 traces the growth of high temperature metallurgy, discusses today's most pressing problems in this interesting field. Relates the importance of high temperature metals in three major metal using industries. *Lesson No. 2* demonstrates, simply and practically, the many tests that can be made . . . their importance. *Lesson No. 3* shows the relationship between room temperature properties to high temperature alloys . . . carbide formation . . . temper brittleness . . . stability. *Lesson No. 4* goes into corrosion . . . hot hardness . . . thermal shock resistance. *Lesson No. 5* discusses allowable working stresses . . . factor for safety . . . design for long service life . . . ASME stresses . . . Lab Data. *Lesson No. 6* deals with melting charge constituents . . . chromium, molybdenum, nickel, titanium, tungsten, vanadium, cobalt, silicon, and many others. *Lesson No. 7* presents the factors that influence high temperature strength . . . *No. 8,* the low and intermediate alloy steels . . . *No. 9,* the straight chromium stainless steels . . . *No. 10,* the austenitic iron-nickel-chromium steels . . . *No. 11,* high temperature superalloys . . . *No. 12,* the low alloy steel for highly stressed high temperature applications . . . *No. 13,* representative service failures . . . *No. 14,* metal properties at processing and fabricating temperatures . . . *No. 15,* selection of alloys for specific application. These helpful, practical lessons . . . the suggestions and comments of your M.E.I. Instructor will bring you up-to-date on high temperature metals technology.

The quality and authority of this course is the natural result of its learned preparation by Dr. Clark, who is a graduate of the University of Michigan with BSE, MSE and PhD degrees. After lecturing in Metallurgical Engineering at the University, he joined the Steel and Tube Division of the Timken Roller Bearing Company, where he is now Metallurgical Engineer, Special Steel Developments. He has developed a number of alloys, holds several patents, has published 100 papers. He is active in many societies and on many technical committees, has received a citation from his University as a distinguished alumnus.

TITANIUM

Millions of dollars have been poured into research and development of Titanium in the United States, England, Japan and other countries since it was first industrialized in 1948. Here is an important new metal of industry . . . one of the most interesting . . . one where firsthand information can be vital to the individual who wants to grow with this great industry.

Authorities throughout the world have been generous in their aid in creating this titanium course . . . it has been prepared by experts throughout the United States, with editorial direction by Dr. Walter L. Finlay, Vice President and Manager of Research, Rem-Cru Titanium, Inc., Midland, Pa.

This course summarizes the metallurgy and technology of titanium . . . provides a detailed picture of where titanium is today, the direction in which it is headed. Each of the 15 lessons covers an important aspect of titanium technology.

In *Lesson No. 1,* Dr. Finlay describes characteristics of titanium, its properties . . . strength-to-weight, tensile strength, crippling strength, corrosion resistance, thermal conductivity and expansion . . . and many applications.

R. L. Powell, Supervisor, Process Research Division, Titanium Metals Corporation of America, Henderson, Nevada, prepared *Lesson No. 2* on the extractive metallurgy of titanium. He discusses production from titanium dioxide, from titanium tetrachloride . . . describes purification, chemical reduction, electrolytic reduction.

Lesson No. 3, by Dr. Finlay, surveys titanium-base alloys . . . gives the ABC's of titanium alloys . . . their structure, heat treatment, etc. In *Lesson No. 4,* Dr. Robert I. Jaffee, Chief, Nonferrous Physical Metallurgy Division, Battelle Memorial Institute, discusses physical metallurgy . . . describes important alloying elements and major contaminants. Dr. Jaffee continues in *Lesson No. 5* with a discussion of beta transformation, heat treatment and thermal stability.

Physical and mechanical properties of titanium are presented in *Lesson No. 6* by D. R. Luster, Chief Supervisor, Research Department, Rem-Cru Titanium, Inc. This lesson reviews what is now known of these important properties and indicates the probable properties that can be expected from yet-to-be developed alloys.

Mr. Luster discusses the metallurgy of titanium in *Lesson No. 7,* and in *Lesson No. 8,* Dr. Finlay describes melting, casting and the powder metallurgy of titanium. Mill processing is covered in *Lesson No. 9* by two experts . . . Dr. Lee S. Busch, Director of Research and Richard J. McClintick, both of Mallory-Sharon Titanium Corporation, Niles, Ohio.

Machining and grinding of titanium is detailed in *Lesson No. 10* by John P. Catlin, of Rem-Cru Titanium, Inc., and in *Lesson No. 11,* George C. Kiefer, of Allegheny Ludlum Steel Corporation, Brackenridge, Pa., discusses corrosion resistance, surface conditioning and chemical analysis.

Final four lessons give outstanding coverage of joining operations, by Glen E. Faulkner, Research Engineer, Battelle Memorial Institute . . . airframe designs, manufacture and uses, by Gordon A. Fairbairn, Supervisor, Materials and Processes, North American Aviation, Inc., Los Angeles . . . titanium jet engine design, by M. E. Cieslicki, Supervisor, Materials Control, General Electric Company, Cincinnati . . . latest developments and trends, by W. Stuart Lyman and E. W. Cawthorne of Titanium Metals Laboratory.

Here is a study course written by outstanding experts, edited by a recognized authority, Dr. Finlay, a graduate of Lehigh University, with a Master's Degree and a Doctor's Degree in Metallurgical Engineering from Yale University. Prior to his association with Rem-Cru, Dr. Finlay was Supervisor of Chemical and Metallurgical Research for Remington Arms Company.

NOW AVAILABLE

Today, the story of the Metals Engineering Institute is dramatized in the long columns of classified advertising. Trained men—*wanted!* Engineers—*wanted*! Industry needs skilled help, needs it badly—and nowhere is this need more severe than in the great industries that produce and use metals.

In a world of metals, there is an insistent demand for men who *know* metals. The American Society for Metals recognized this need three years ago. It studied these requirements of the industry it had served for forty years. It thoroughly investigated how these training requirements were being served.

As a result of this intensive investigation . . . of consultation with industry . . . the Society created the Metals Engineering Institute and projected a series of study courses to meet modern training requirements of industry. In the years since formation of MEI, the outstanding experts and authorities who have long known and respected the American Society for Metals have been engaged in the preparation of nearly two-score metals courses. Some of the most important of these courses are ready now—more will be ready soon.

Today, then, men who want to get ahead in the giant metal industry . . . men who *want* to know about metals . . . men like you . . . can study, in your own spare time, the authoritative, the new shaped-by-industry courses—at home or on-the-job.

You can solve—and solve correctly the problems that involve metals . . . you can forge to the front, assure *your* success with the outstanding study courses that are ready for you—now. You can have confidence in ASM and in the assurance I give you that MEI will assist you in every way.

Anton deS. Brasunas

Anton deSales Brasunas, *Director*
METALS ENGINEERING INSTITUTE

Dr. Anton deSales Brasunas was appointed Director of the Metals Engineering Institute after a long search for just the right man who, by education and experience, would most ideally qualify for this important post. Dr. Brasunas came to MEI from the University of Tennessee where he was associate professor of metallurgical engineering. Prior to that time, he was associated with the Oak Ridge National Laboratory and with Battelle Memorial Institute. He is a graduate of Antioch College, received his MSc. degree from Ohio State University, his Sc.D degree from Massachusetts Institute of Technology.

Metals Engineering Institute
This certifies that
Austin Knight
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under direction of Metals Engineering Institute, a division of American Society for Metals, and in testimony thereof has been awarded this
Certificate
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MEMO Training Directors and Employers

MEI Study Courses are ideally adapted for in-plant, on-the-job or after-hours training. Cleveland Pneumatic Tool Co. and Wallingford Steel Co., for example, are making excellent use of the "Elements of Metallurgy" and the "High Temperature Metals" courses, respectively. Other courses ready *now* cover Heat Treatment and Titanium.

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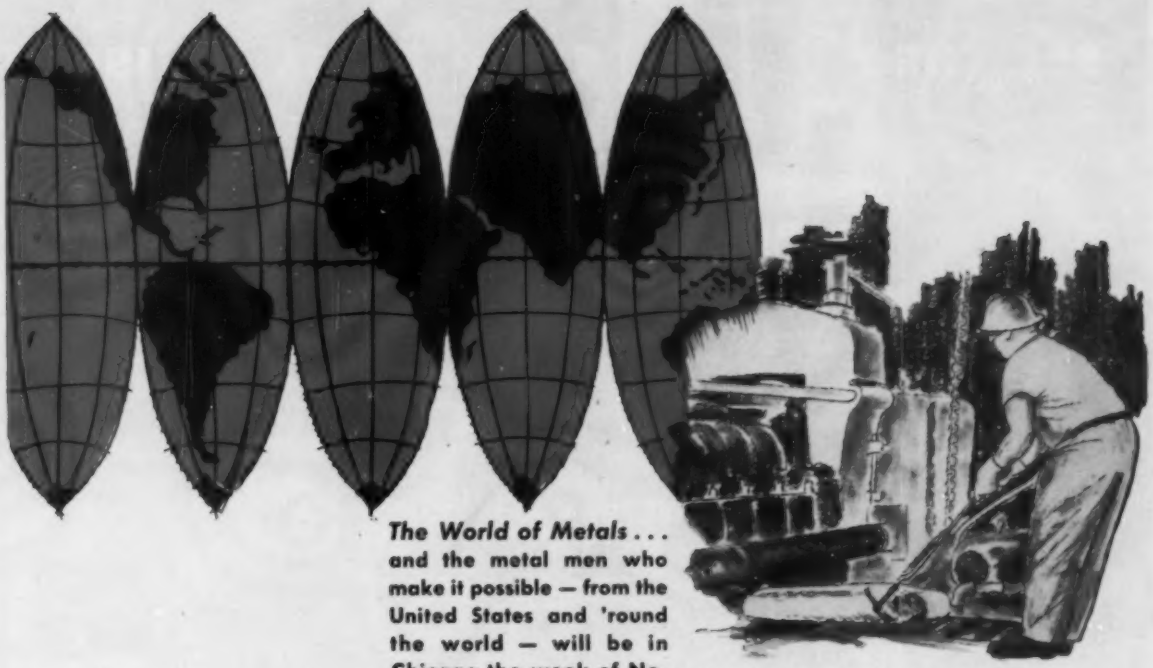

The World of Metals . . . **and the metal men who make it possible — from the United States and 'round the world — will be in Chicago the week of November 4 to attend the**

39th National Metal Exposition
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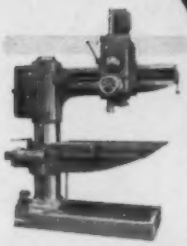

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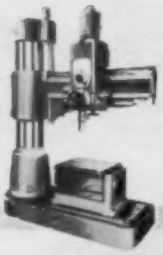

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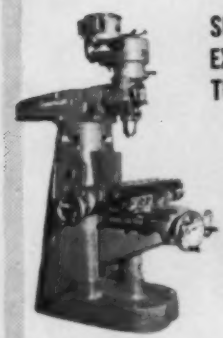

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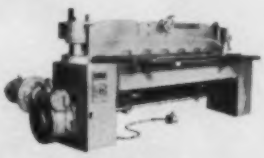

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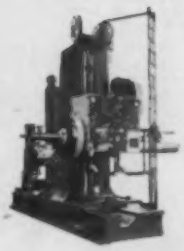

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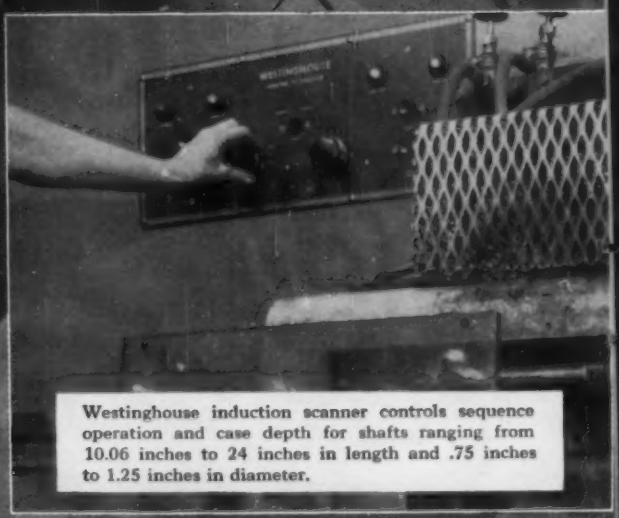

Westinghouse induction scanner controls sequence operation and case depth for shafts ranging from 10.06 inches to 24 inches in length and .75 inches to 1.25 inches in diameter.

PRODUCT AND **PROFIT** IMPROVEMENT

BURGESS-NORTON?

500,000 rocker arm shafts hardened—and no rejects ...with Westinghouse Induction Heating!

At Burgess-Norton Mfg. Co., Geneva, Illinois, Westinghouse Induction Heating is producing five important advantages in hardening automotive engine rocker arm shafts.

1. No cracking.
2. No distortion.
3. Shafts harden evenly to uniform case depth.
4. Overall savings in manpower.
5. Partial stress relief because of stored heat within the shaft.

The entire operation is automatic. Shafts are conveyed to the induction unit, jigged, spun at 400 rpm while heating to 1550°F., then quenched in a water spray . . . all in just 3.25 seconds for each of six sections on a shaft.

This is exciting, important news for many plants concerned with hardening, heat treating, joining, forging or other metalworking operations. Westinghouse Induction Heating, *within seconds*, puts heat *exactly* where you want it day after day, week after week, without variation. This precision and uniformity is vital with today's high speeds and close tolerances.

Westinghouse Induction Heating units are clean, cool, streamlined and space saving. Westinghouse engineering creates for your individual requirements integrated production line equipment that speeds output, cuts costs, brightens your profit picture.

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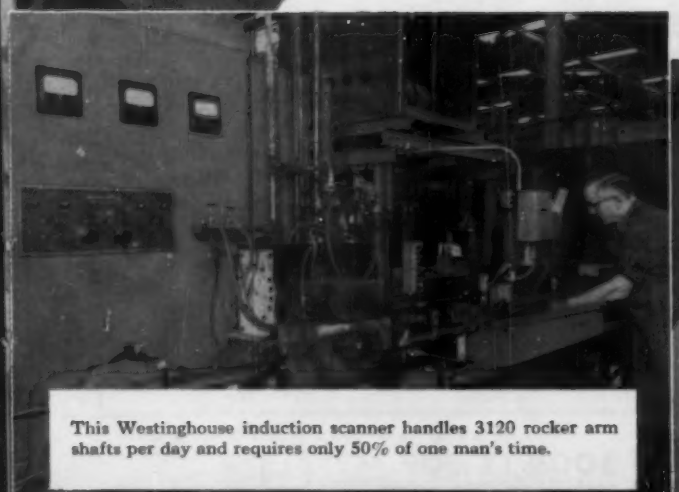

This Westinghouse induction scanner handles 3120 rocker arm shafts per day and requires only 50% of one man's time.

WITH WESTINGHOUSE INDUCTION HEATING

BUT MAYBE INDUCTION HEATING IS NOT FOR YOU...LET'S FIND OUT

Telephone collect EDmonson 6-2300, or return this coupon to SALES MANAGER, Industrial Electronics Dept., Westinghouse Electric Corporation, P. O. Box 416, Baltimore 3, Maryland.

I believe that we qualify for Westinghouse Induction Heating. _____Please have your engineer call, _____Please send literature. We make_____(item) from_____ (metal or alloy). Each piece is approx._____(size) and weighs approx._____. We work in temperature range of_____and handle approx._____ per hour. We are interested in: _____Forging_____Hardening _____Joining_____Other.

Please describe briefly_____

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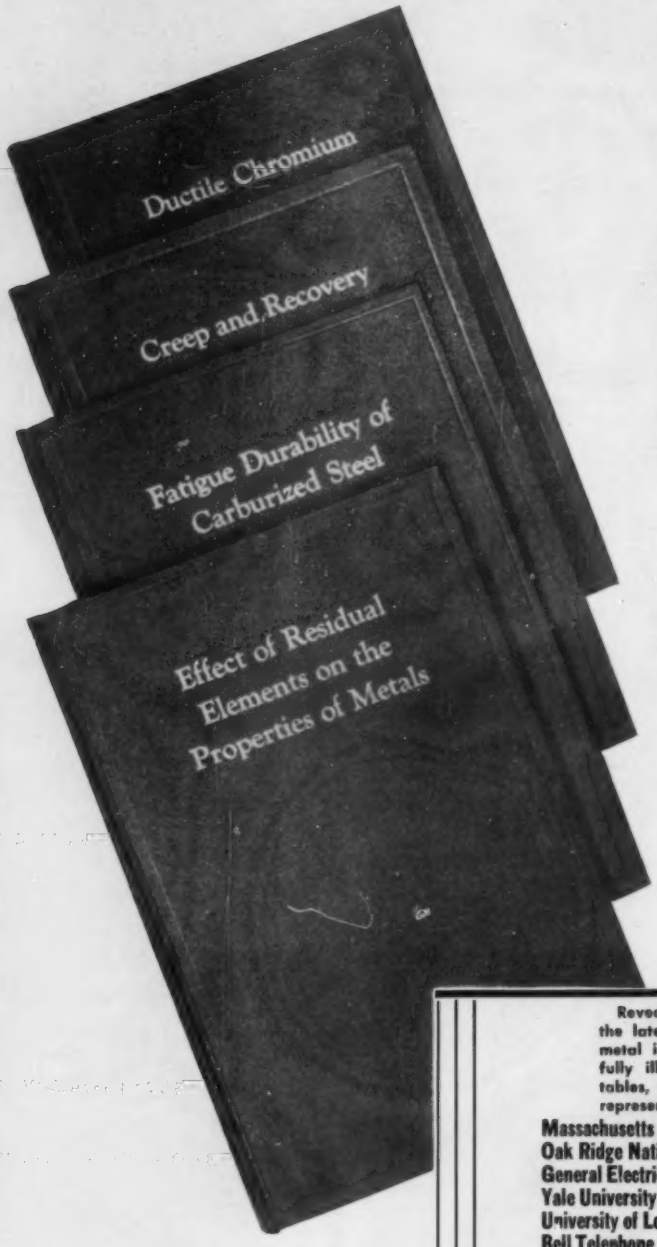
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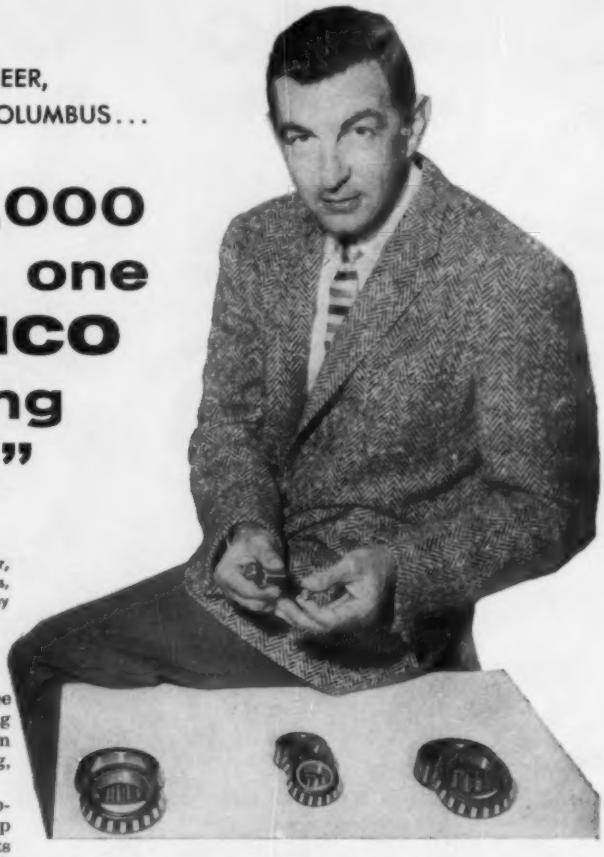
THE TIMKEN ROLLER BEARING COMPANY, COLUMBUS...

"We process 4,000 lbs. of rollers in one load with ALMCO barrel finishing equipment"



MR. FRED ALBRIGHT, Assistant Chief Engineer, The Timken Roller Bearing Company, Columbus, displays rollers processed in two-ton batches by rugged Almco equipment.

AT COLUMBUS, OHIO, the Timken Company runs three shifts on rollers in a range of sizes. After heat treating and oil removal, rollers go to the Almco barrel section for cleaning-up of insert identification, radius polishing, and coloring.

Prior to this the Timken Company used other equipment, but it turned out to be a bottleneck that took up too much space. Maintenance costs were high, and its messy operation did not conform to the Company's high standards of plant housekeeping.

ALMCO SYSTEM REQUIRED 50% LESS FLOOR AREA — In cooperation with Timken Company engineers, Almco designed specially engineered heavy duty equipment for their system that raised output to production requirements... replaced the older equipment with a clean, controlled operation... and reduced floor area requirements by more than 50%.

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It calls for equipment that will stand up under a punishing, round-the-clock production schedule. In this highly abrasive operation, Almco barrels at the Timken Company have been re-lined only *once* in two years!

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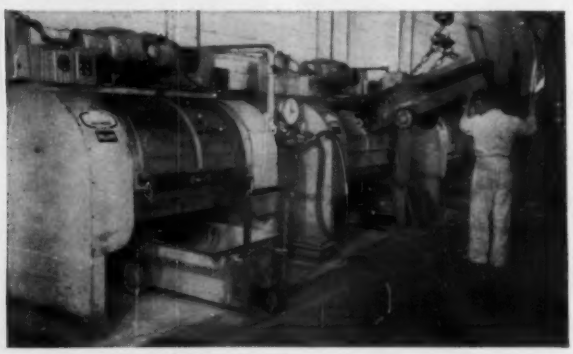
If you are interested in improving product quality and appearance, saving manpower and reducing your deburring and finishing costs, send your sample parts and specifications to the Almco lab. Or write on your company letterhead requesting an Almco engineer to visit your plant.



Cooperation between Timken Company and Almco engineers has resulted in efficient Almco installations in other Timken Company plants. The Timken Company at this time has a total of twelve DB-400 units and a DB-50. Minimum space is required for high-volume production... plant floor stays clean and safe.

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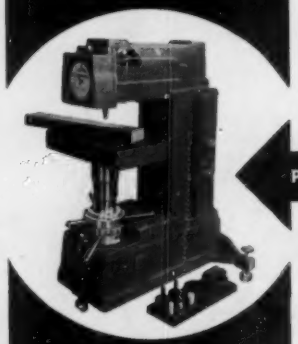

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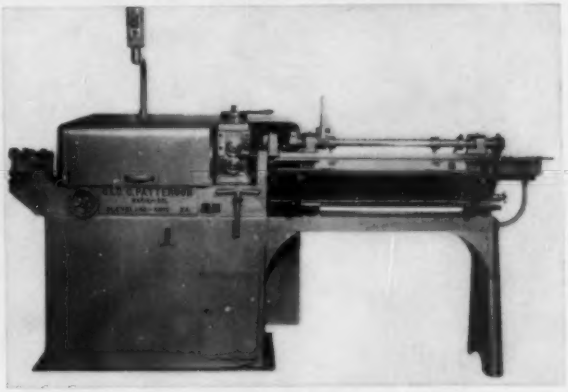

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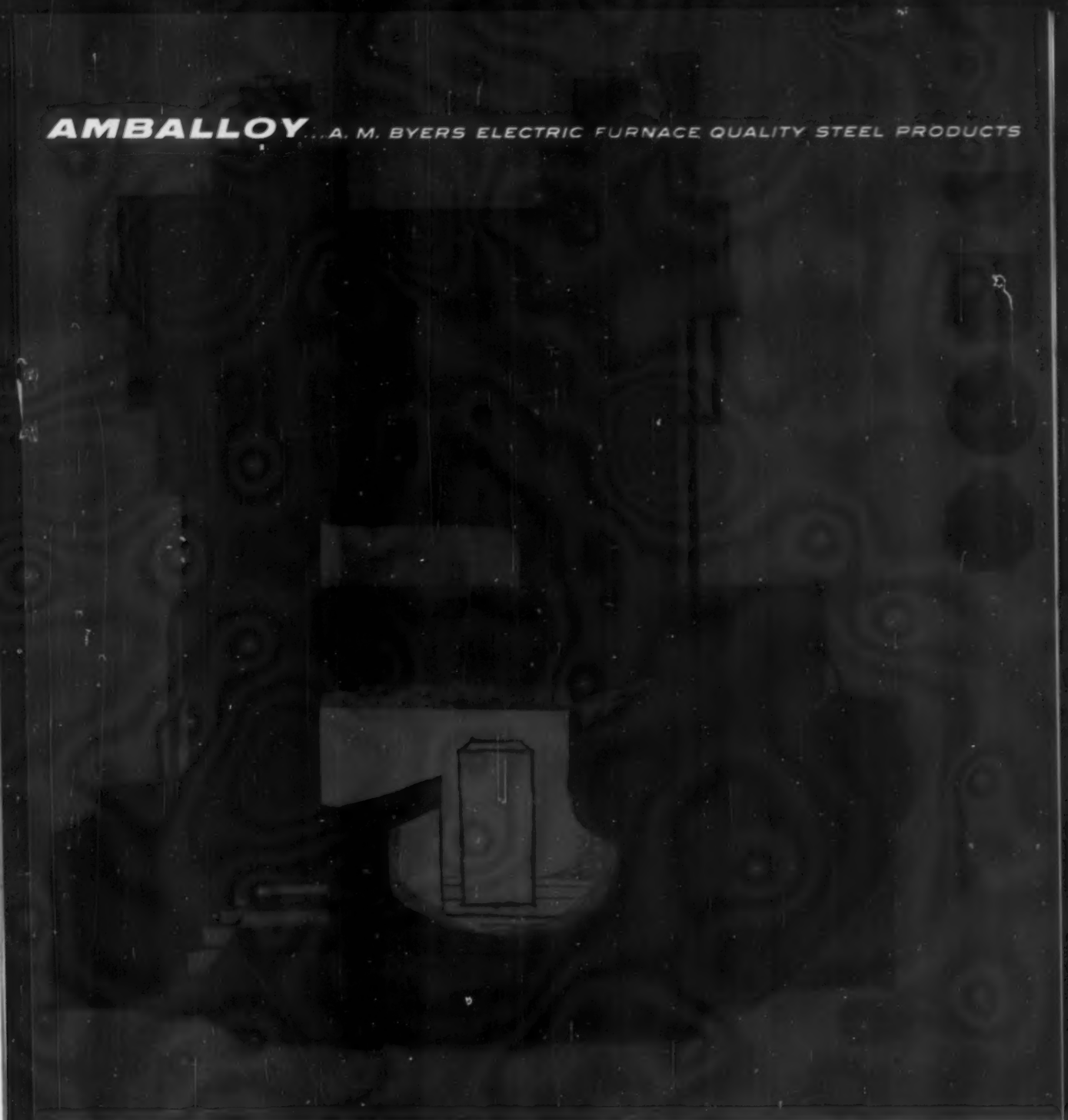

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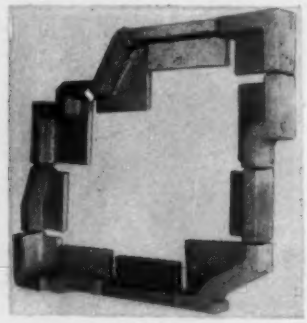

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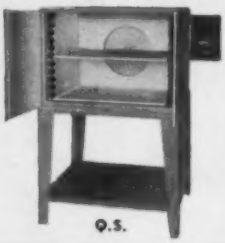

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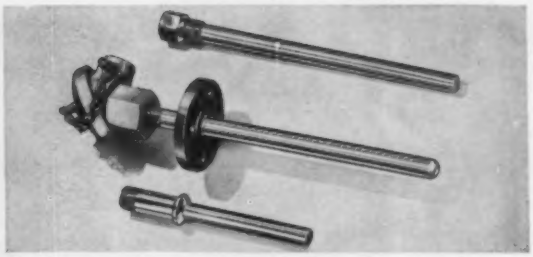

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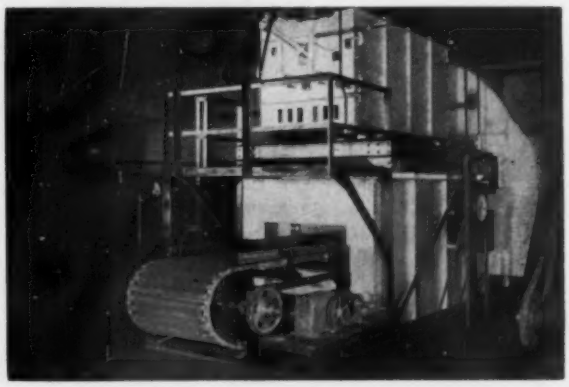

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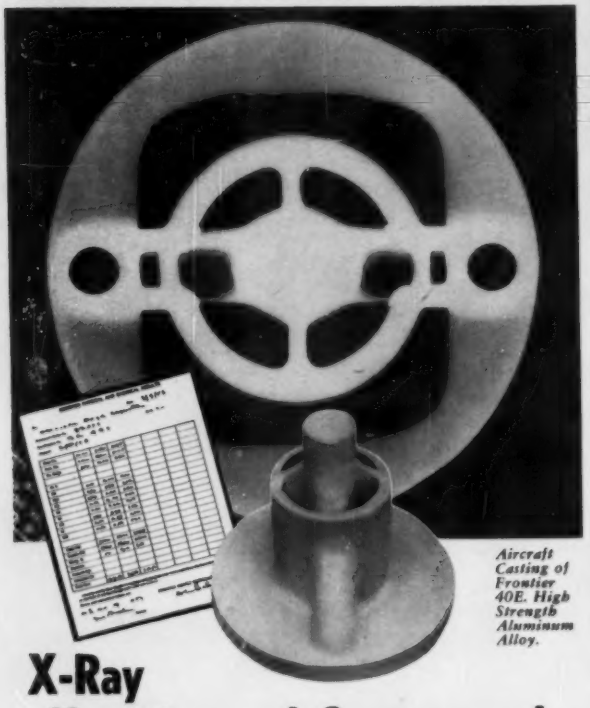

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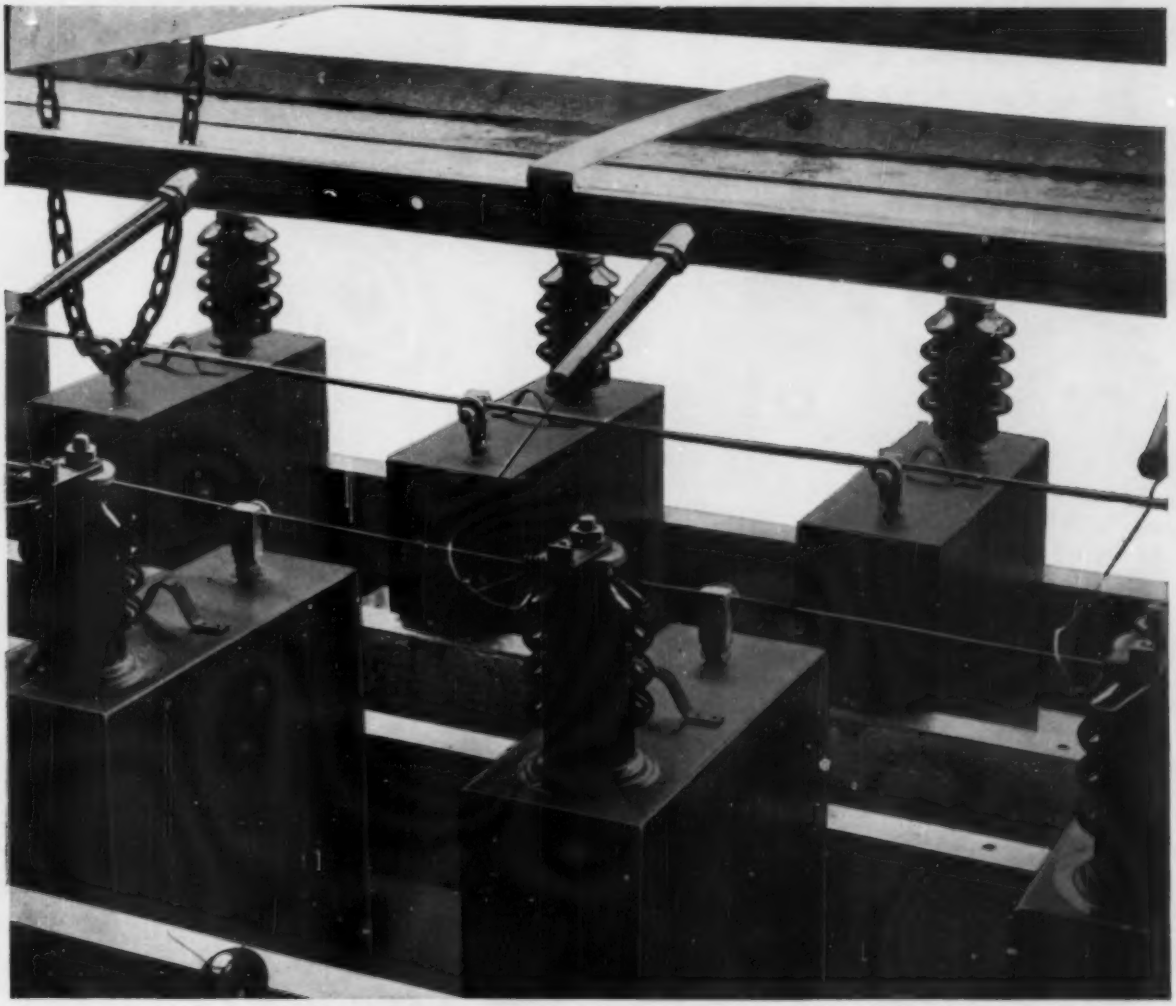

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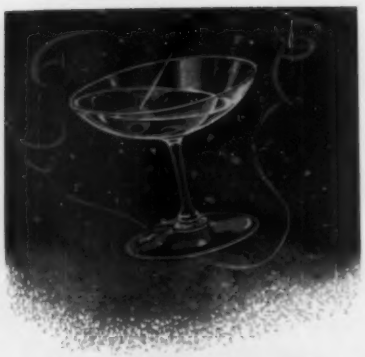

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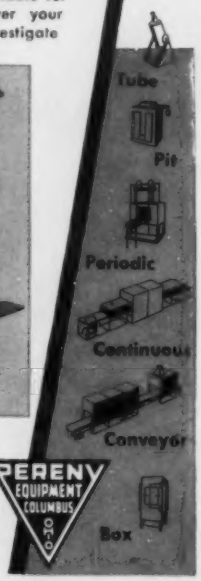

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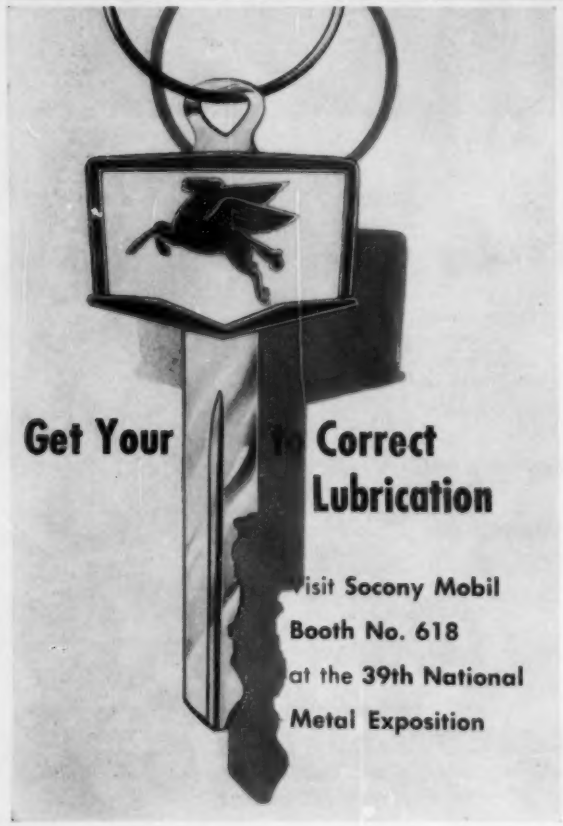

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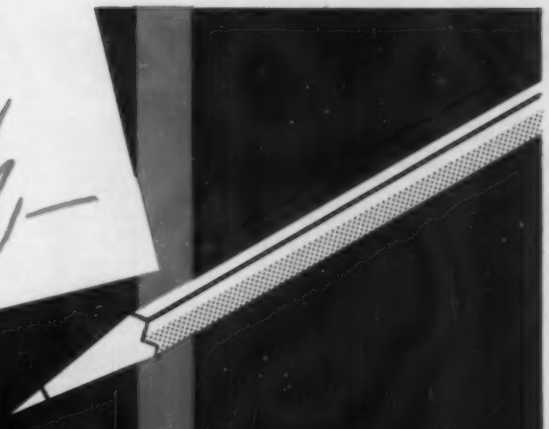

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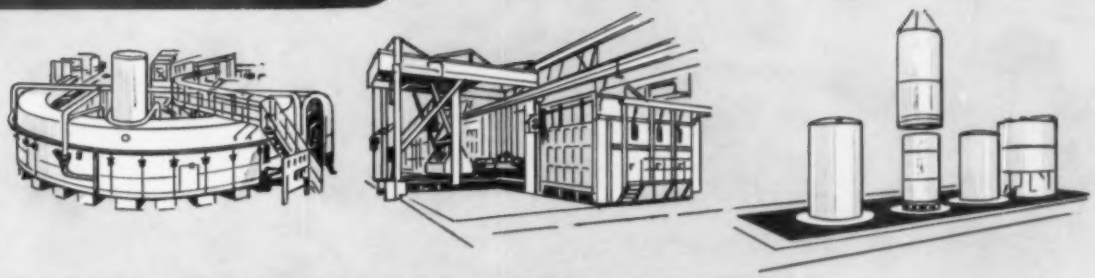

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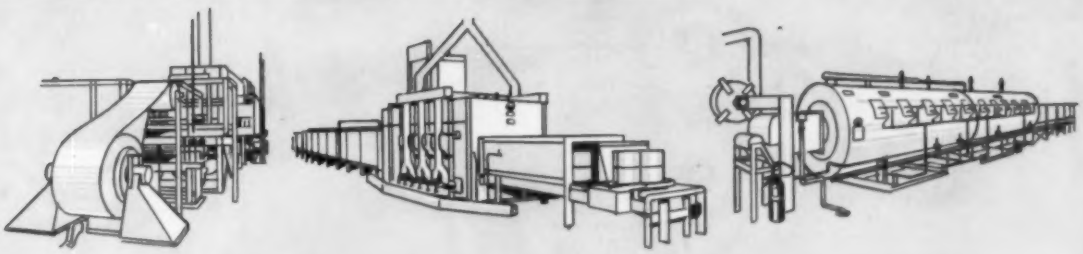

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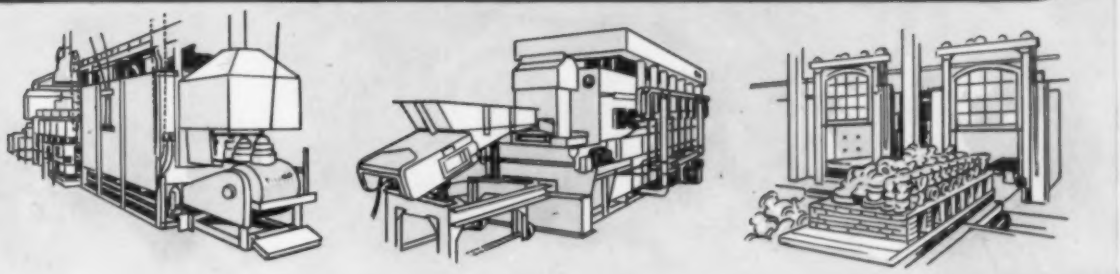

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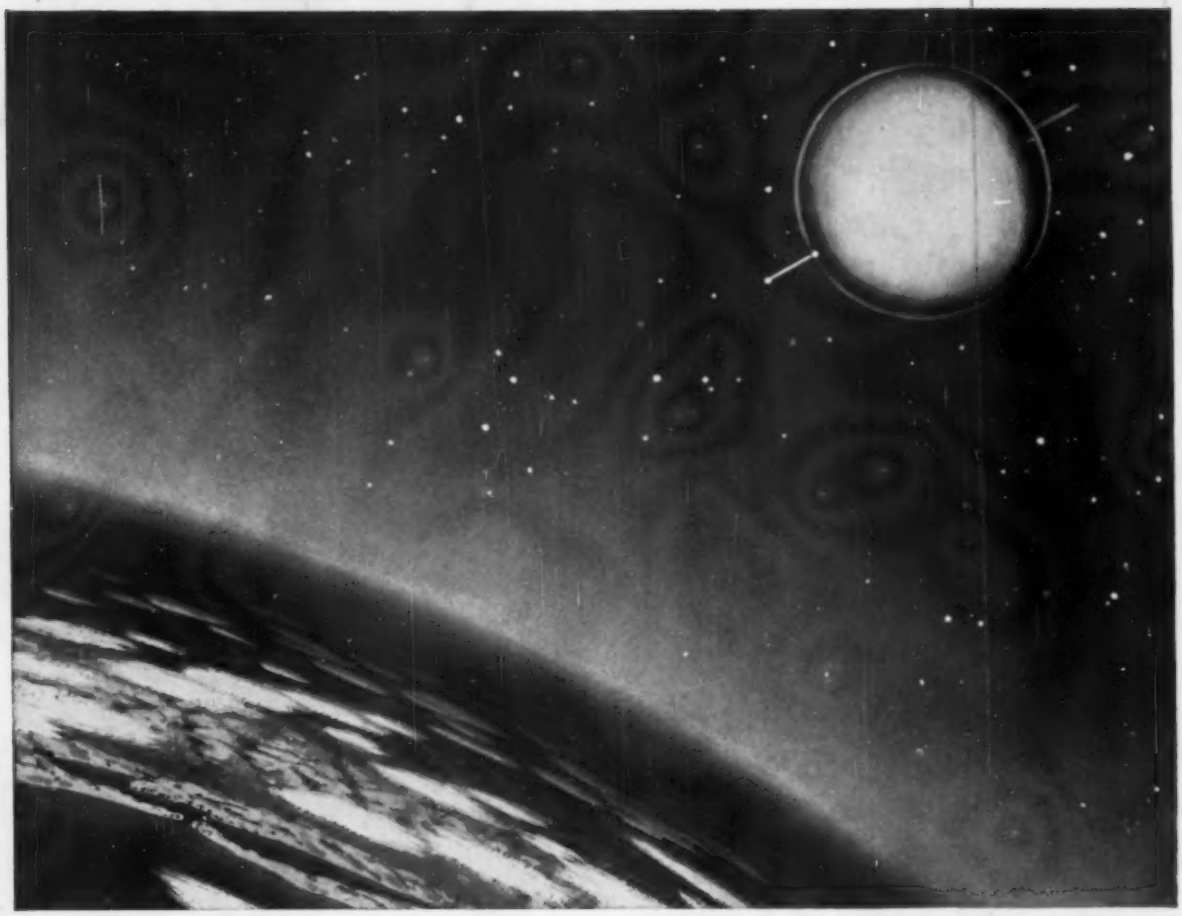

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